Digital Mobility Strategy

Digital Mobility Strategy | DMS

Summary
The further development of mobility services into a sustainable, future-proof, and digitally supported mobility system is one of the most significant changes for Hamburg and at the same time one of the major challenges of this decade. Digital mobility refers to the use of digital technologies, such as smartphone apps, sensors, artificial intelligence, and networking to make the mobility system more efficient, flexible, and user-friendly. The focus is on understanding and taking into account the needs, wishes, and requirements of the users. The implementation of an innovative strategy in the fields of digitalisation, automation, and connectivity in mobility forms a fundamental basis for the realisation of the mobility transition, as outlined in the Mobility Transition Strategy (Document 22/13670).

Hamburg will host the world's largest mobility congress in 2025 and 2027. The 'Global Public Transport Summit' organised by the Union Internationale des Transports Publics (UITP) will attract worldwide attention. As Germany's leading smart city for mobility, Hamburg aims to gradually establish a mobility system tailored to the needs of users and aligned with the mobility transition by 2030. Automated and networked services will make local public transport even more attractive. Vulnerable road users such as pedestrians and cyclists are better protected and the growing volume of goods traffic will be managed more efficiently.
Traditional transport services will be complemented by on-demand shuttles, some of which will operate autonomously and sharing economy solutions. In this way, Hamburg will consolidate its position as a leading European metropolis for digital mobility and promote technological advancements beyond its borders.

To meet the changing requirements, the 2016 Strategy for Intelligent Transport Systems and Services (ITS) – 'ITS Strategy for Hamburg' – has been further developed into the 'Digital Mobility Strategy' (DMS). The progress achieved so far is showcased in nine development paths, outlining the roadmap for the digitalisation of mobility up to 2030.

Digitalisation is a cross-departmental issue that requires cooperation between different government bodies. The implementation of the Digital Mobility Strategy is primarily organised and led by the MInistry for Transport and Mobility Transition (Authority for Transport and Mobility Transition). The subsidiary New Mobility Solutions Hamburg GmbH (NMS), established in summer 2022 by the main public transport company Hochbahn, coordinates and supports this process in consultation with the participants from the working and steering committee on digital mobility.

Hamburg is using the experience gained from the successful ITS World Congress 2021 to exploit the opportunities offered by digitalisation and automation to further expand the mobility system. The central instruments and measures are supported as part of strategic portfolio management in the Digital Mobility Strategy.

In 2024, the project portfolio comprised 237 projects in which new technologies and approaches were tested and demonstrated. 70 active projects and 25 projects in preparation (as of March 2024) show that the mobility digitalisation is being driven forward. In the future, the focus will be on rolling out priority projects so that they can realise their potential across the entire metropolitan region.

The expansion and use of co-operative systems between vehicles and infrastructure in Hamburg continues to progress. By 2030, successfully tested 'Cooperative Intelligent Transport Systems' (C-ITS) services are set to be rolled out and available citywide. These services aim to prioritise bus and bicycle traffic, enhance the safety of cyclists and pedestrians, and strengthen the overall sustainable transport network.

A key component of the *Hamburg-Takt* which is an initiative with the aim to provide access public transport within five minutes, 24/7 to all Hamburg residents, is the enhancement of customer-centric services for better quality and service. This includes supplementing the conventional public transport network with a comprehensive on-demand service integrated into the city's transport system (such as MOIA [app-based ride-sharing service], hvv hop [on-demand shuttle service], taxis, etc.). By 2030, this flexible service will be largely based on autonomous vehicles. However, vehicles with drivers should also be available for people with special transport and assistance needs.
The new public mobility services, alongside traditional public transport, shared mobility, and cycling infrastructure, support a sustainable mobility transition in Hamburg. In the rapid transit sector (U-Bahn [underground] and S-Bahn [urban railway]), the potential of

digitalisation is also being utilised to implement a (semi-)autonomous, more efficient, and more resilient operation. This includes the fully automated U5 underground line, the continuation of the high-level automation of today's DC network for the S-Bahn Hamburg as the 'Digital S-Bahn Hamburg', as well as the partial automation of the existing network on sections of the U2 line and the entire U4 line ('U-Bahn100'). The first fully automatic underground line of the Hamburger Hochbahn [elevated and underground railway], the U5, will be in operation from 2027 on the first section between Bramfeld and City Nord – initially in trial operation between City Nord and Sengelmannstrasse.

The hvv switch mobility platform offers a networked system of digitally bookable tickets, vehicles, and bicycles. The hvv switch app will allow users to access and book all available transport services within the hvv area. The aim is to effectively integrate the different modes of transport within the sustainable transport network and provide users with precise information for intermodal travel chains. The plan is to expand hvv switch points to 222 locations by 2024, while continually advancing the integration of mobility providers for ride pooling, car sharing, and e-scooter sharing.

To meet the increasing demands for future mobility and traffic management, the Ministry for Transport and Mobility Transition plans to develop and gradually implement a Mobility Operating System (MOS). Based on the '#transmove' project, where AI-supported software creates mobility forecasts, MOS aims to unify the various urban specialist applications and subsystems of operational traffic and mobility management. This will provide a common decision-making basis for key urban control and operations centres, enable real-time information exchange, and offer scenario-based decision support.
The digital infrastructure will be enhanced with system components for communication and sensors to continuously and automatically capture mobility and traffic data. This also includes digital car park management. In the future, data will increasingly be made available via standardised data rooms and interfaces. The Urban Data Platform Hamburg (UDP_HH, www.urbandataplatform.hamburg) is already a powerful data hub for this purpose. Interoperable urban mobility twins, the nationwide Mobilithek, and the Federal Mobility Data Space (MDS) promote comprehensive exchange and aim to gradually provide new data services. [The Mobilithek is a platform for exchanging digital information between mobility providers, infrastructure operators, transport authorities, and information providers.]

The Digital Mobility Strategy is intended to highlight the strategic goals and describe the ways in which Hamburg can continue to use the opportunities offered by digitalisation to support the mobility transition and make mobility more needs-based, convenient, safe, and efficient for its citizens. Successful implementation will continue to require co-operation between all authorities, industry, and science.

Contents

1 Introduction 8
2 Insights from the last strategy process and the current initial situation 10
2.1 ITS strategy and ITS progress report (2016-2021) 11
2.2 Lessons learnt from the ITS strategy until 2021 15
3 Mission statement, strategic goals, and development paths 16
3.1 Target architecture of the Digital Mobility Strategy 16
3.2 Development paths 19
3.2.1 Development path for mobility twins 20
3.2.2 Traffic management development path 25
3.2.3 Mobility platform development path 29
3.2.4 Development path for autonomous on-demand shuttles 32
3.2.5 Digital underground and urban rapid transit system development path 37
3.2.6 Cooperative systems development path 40
3.2.7 Digital car park management development path 44
3.2.8 City and port logistics development path 47
3.2.9 Maintenance management development path 49
4 Digital mobility organisational structures 52
5 Appendix 55
5.1 Sources and reference documents 55
5.2 Selected measures proposed by participants from strategy development workshops 56
5.3 Target achievement for the ITS strategy action areas by 2021 57

List of figures

Figure 1: Digital ranking for Germany's major cities in the mobility sector by Bitkom e.V. (2023) 8
Figure 2: Milestones in the implementation of the ITS strategy 10
Figure 3: Number of ITS projects in the ITS dashboard (as at 19 September 2023) 11
Figure 4: ITS strategy action areas 11
Figure 5: Impressions of the ITS World Congress 2021 in Hamburg © ERTICO 12
Figure 6: Project overview in RealLabHH 14
Figure 7: Target architecture of the Digital Mobility Strategy (DMS) 16
Figure 8: Legend of the project development paths 19
Figure 9: Development path for mobility twins | From traffic data collection and provision to task-specific mobility twins 20
Figure 10: Control cycle of the Sharing Mobility specialist twin 21
Figure 11: Conceptual structure of the urban digital twin according to CUT project (Schubbe et al. 2023) 23
Figure 12: Traffic management development path | From demonstrator to digital and automated traffic management 25
Figure 13: '#transmove – AI-supported mobility forecasts' enables mobility forecasts and a comment function for ad-hoc traffic planning based on the mobility dashboard 26
Figure 14: Hamburg urban air mobility projects and activities 27
Figure 15: Mobility platform development path | Digital sales infrastructure in public transport 29
Figure 16: Development path for autonomous on-demand shuttles | From the first on-demand transport services to autonomous ride pooling 32
Figure 17: The road to 10,000 autonomous ride pooling vehicles (source: MOIA) 34
Figure 18: Digital underground and rapid transit system development path | From the feasibility study to partially and fully automated rail transport 37
Figure 19: Cooperative systems development path | From C-ITS test fields to the rollout and operation of C-ITS services 40
Figure 20: C-ITS services in Hamburg (source: State Office for Geoinformation and Surveying) 43
Figure 21: Car park management development path | From parking space detection to complete digital parking management 44
Figure 22: City and port logistics development path | From smart city logistics to autonomous goods transport 47
Figure 23: Maintenance management development path | From digital condition recording to automated maintenance management 49
Figure 24: ITS projects (Ministry for Transport and Mobility Transition, Department of Economics and Innovation, State Office for Roads, Bridges and Waterways) with funding shares – as of: December 2023 53
Figure 25: Selected proposed measures from the seven ITS workshops in the period (Q2 2022–Q1 2023) for the strategy update 57

List of abbreviations

AFGBV	Autonomous Vehicles Authorisation and Operation Ordinance
ATO	Automatic train operation
aVME	Automated traffic volume recording
AVP	Automated valet parking
BiDiMoVe	'Bidirectional, multimodal, networked' initiative. The aim of the project is this dynamic and needs-based prioritisation of public transport at traffic lights by means of networking
BMDV	Federal Department of Transport and Digital Infrastructure
BOS	Authorities and organisations with security tasks real-time routing
B+R	Bike and ride
BVM	Ministry for Transport and Mobility Transition
BWI	Department of Economics and Innovation
BWVI	Department of Economics, Transport and Innovation
CAM	Cooperative Awareness Messages (cooperative perception messages)
CCAM	Cooperative Connected and Automated Mobility
CIIK	C-ITS Infrastructure Expertise Team
C-ITS	Cooperative Intelligent Transport Systems
CUT	Connected Urban Twins
DaQuAI	Data quality through AI (artificial intelligence)
DB	Deutsche Bahn
DSD	*Digitale Schiene Deutschland* [Digital Rail Germany]
ERTICO	European Road Transport Telematics Implementation Coordination Organisation
ETCS	European Train Control System
R&D	Research and development
Gaia-X 4 ROMS	Support and remote operation of automated and networked mobility services
GoA	Grade of Automation
HEAT	Hamburg Electric Autonomous Transportation
HHLA	Hamburger Hafen- und Logistik AG [Hamburg Port and Logistics AG]
HPA	Hamburg Port Authority AöR (Institution under public law)
hvv	Hamburger Verkehrsverbund [Hamburg Transport Association]
I2V	Infrastructure-to-Vehicle (infrastructure-vehicle-communication)
IKEM	Institute for Climate Protection, Energy and Mobility e. V.
ITS	Intelligent Transport Systems (Intelligent transport systems and services)
CEP service	Courier, Express, and Parcel service
AI	Artificial intelligence
KIT	Karlsruher Institut für Technologie [Karlsruhe Institute of Technology]
LBV	State Traffic Authority
LGV	Agency for Geoinformation and Surveying
LiDAR	Light Detection And Ranging; a method for optical distance and speed measurement
LIHH	Logistics Initiative Hamburg
Lkw	Lorry
LSA	Traffic lights
LSBG	State Office for Roads, Bridges and Waterways
MaaS	Mobility-as-a-Service
MIV	Motorised private transport
MOS	Mobility Operating System
MoU	Memorandum of Understanding (letter of intent)
NLZ	New central control for traffic lights system
NMS	New Mobility Solutions
NPM	National Platform for the Future of Mobility
OBU	On-board unit
ÖPNV	Public local transport
ÖV	Public transport
Pkw	Passenger car
PMO	Project Management Office
P+R	Park and Ride

RealLabHH	Hamburg real-world lab
RLVW	Red Light Violation Warning
ROKS-HH	Rollout of cooperative systems in the Hanseatic City of Hamburg
RSU	Roadside Unit
SAE	Society of Automotive Engineers
DMS	Digital Mobility Strategy
SmaLa	Smart loading zones
SPTI	Signal Phase and Timing Information
StVG	German Road Traffic Act
TaBuLa	Test centre for automated buses in Lauenburg
TAVF	Test Track for Automated and Connected Driving
TIMS	Traffic Information Management System
TJAW	Traffic Jam Ahead Warning
TLF	Traffic Light Forecast
TTG	Time-to-Green
TU	Technical University
UAM	Urban Air Mobility
UDP	Urban Data Platform
UITP	Union Internationale des Transports Publics
USP	Urban Smart Park
VHH	Hamburg-Holstein Transport Authority
VRU	Vulnerable road users
V2V	Vehicle-to-Vehicle (vehicle-to-vehicle communication)
V2X	Vehicle-to-Everything (Vehicle communication system that combines V2I (Vehicle-to-Infrastructure), V2N (Vehicle-to-Network), V2V (Vehicle-to-Vehicle), V2P (Vehicle-to-Pedestrian), V2D (Vehicle-to-Device))

1 Introduction

Hamburg is an attractive metropolis with steady growth and strong national and international appeal. Its attractiveness and performance, quality of life, and employment opportunities are directly linked to attractive mobility options for everyone. It is in Hamburg's interest to provide and continuously develop a high-performance, future-proof, and affordable transport system for all modes of travel. At the same time, Hamburg is faced with the challenge of countering the effects on the climate, health, and quality of life associated with a constantly increasing demand for mobility.

With the second update of the Hamburg Climate Plan, Hamburg has committed to reducing CO_2 emissions by 70 percent by 2030 compared to 1990 levels and to achieving net CO_2 neutrality by 2045. In addition, the Hamburg Senate has set itself the goal of increasing the proportion of journeys made using eco-friendly modes of transport (public transport, cycling, and walking) to 80 percent over the course of the decade. Central programmes such as the mobility transition strategy, the Hamburg-Takt initiative, the cycling strategy, and the electrification of urban fleets contribute to these goals. In addition to the demands of climate and environmental protection, digitalisation is reinforcing the trend towards connectivity, autonomous systems, digital technology platforms, new business models, and services.

Alongside extensive expansion measures to achieve climate and mobility goals, Hamburg, as one of Germany's leading cities, is focusing on the digitalisation and automation of transport to provide a modern, sustainable, and efficient mobility system that is closely aligned with the needs of its users. The digitalisation of mobility is approached comprehensively and across all modes of transport.

Hamburg has established itself as a city of future mobility. Thanks to the close collaboration between authorities, businesses, and academia, as well as the promotion of industry partnerships, Hamburg has created an innovative environment for new forms of mobility and has already achieved significant milestones. After successfully hosting the ITS World Congress in 2021, Hamburg will once again gain international attention in 2025 and 2027 as the venue for the world's largest mobility congress, the UITP Global Public Transport Summit. In the Smart City Index by Bitkom e.V., Hamburg secured the top position in the mobility category in 2023. This is the third time that Hamburg has topped the digital ranking in the field of mobility after 2020 and 2021.

Mobilität			
Platz	**Tendenz**	**Stadt**	**Index**
1	↗ +1	Hamburg	**98.4**
2	↘ -1	Nürnberg	**91.3**
3	↗ +3	Dresden	**90.1**
4	↘ -1	Berlin	**87.3**
5	↗ +4	Aachen	**86.7**
6	↑ +15	Frankfurt am Main	**82.7**
7	↑ +13	Bonn	**82.1**
8	↘ -3	Köln	**82.1**
9	↗ +3	Potsdam	**80.7**
10	↗ +1	Bochum	**80.6**

Figure 1: Digital ranking for Germany's major cities in the mobility sector by Bitkom e.V. (2023)

Hamburg successfully implemented the Hamburg Real-World Lab (RealLabHH) project as part of the National Platform for the Future of Mobility and hosted the National Cycling Congress in 2021. With over 230 ITS and digital mobility projects to date and participation in the Mobility Data Space, Hamburg offers a wide range of innovative solutions on local, national, and international levels for a sustainable mobility system of the future.

The Digital Strategy for Hamburg (document: 21/19800) and the Mobility Transition Strategy (document: 22/13670) form the basis for the digitalisation of mobility in Hamburg. There are also overlaps with other (sub-)strategies:

- The Hamburg-Takt Strategy (2020)
- The second update of the Hamburg Climate Plan (document: 22/12774)
- DS#2 – Update of the initial Digital Strategy by the Department for Economy, Transport and Innovation (BWVI), from which the Digital Mobility Strategy, among others, is derived (2024)
- Port Development Plan 2040 ‘With innovative strength and quality for sustainable value creation’ (document: 22/12205)
- Urban Logistics Hamburg – Strategy for the Last Mile (2021) (document: 22/5939)
- The cross-departmental project to develop a strategy for electromobility and charging infrastructure.
- The ITS Strategy for Hamburg from 2016 and its update in 2018 for the continuous digitalisation of the transport system
- The Hamburg Green City Plan – master plan for the design of sustainable and emission-free mobility in Hamburg as part of the Clean Air Immediate Action Programme 2017-2020

To address the changing conditions, the ITS Strategy is being updated and revised as part of the Digital Mobility Strategy.

2 Insights from the last strategy process and the current initial situation

Hamburg recognised the opportunities of digitalisation in the mobility sector early on. In April 2016, Hamburg became the first city in Europe to adopt an ITS strategy..

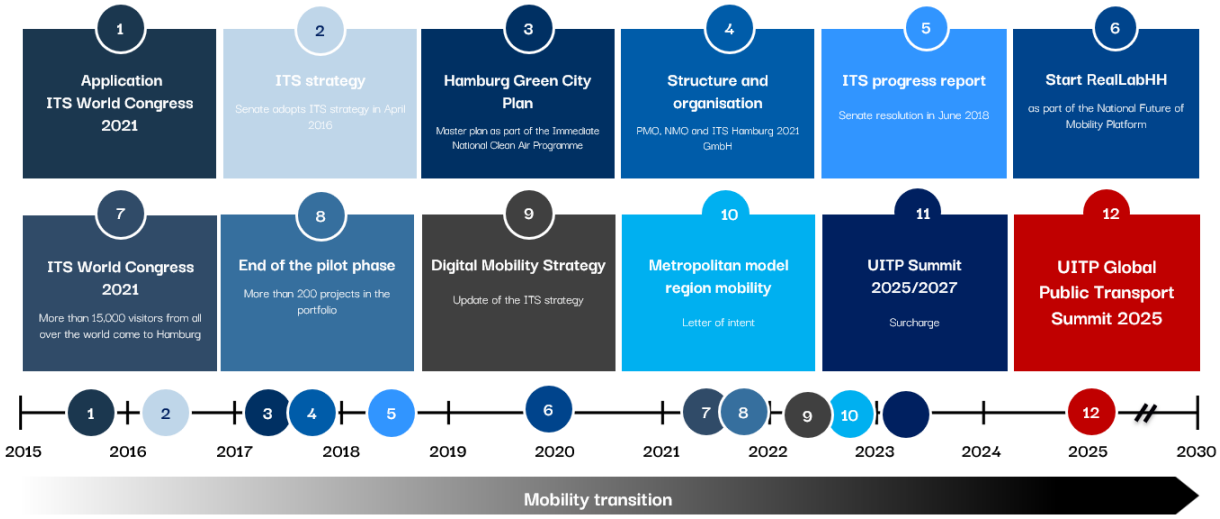

Figure 2: Milestones in the implementation of the ITS strategy

In 2018, the Hamburg Green City Plan established a master plan for sustainable and emission-free mobility as part of the Clean Air Immediate Action Programme. Based on this plan, numerous funding approvals were granted to Hamburg ITS projects. At the same time, effective organisational structures were implemented, including a Project Management Office (PMO) at Hamburger Hochbahn AG, a Network Management Office at the Logistics Initiative Hamburg, and the city's ITS Congress Management Company. In 2018, the ITS Progress Report was drafted, outlining the implementation goals for the six action areas of the ITS strategy for the years 2021 and 2030, which were approved by the Senate. Twelve sub-projects were implemented with RealLabHH in 2020-2021 as part of the National Platform for the Future of Mobility (NPM). Following the successful application in October 2015, the 27th ITS World Congress 2021 took place six years later in Hamburg with more than 15,000 visitors, making it the largest congress ever held in terms of visitor numbers.
In the year of the World Congress, 2021 also saw the successful completion of the majority of over 200 ITS projects. This milestone aimed to showcase interesting projects and content at the World Congress with the intention of rolling them out city-wide if deemed suitable.
Following the ITS World Congress in 2021, Hamburg engaged with the Federal Department of Transport and Digital Infrastructure to establish the Hamburg metropolitan region as an area where digital mobility can be experienced. In 2022, a memorandum of understanding was signed between Hamburg and the Federal Department of Transport and Digital Infrastructure to collaborate on digital mobility projects and establish the 'Metropolitan Model Region of Mobility Hamburg'. The goals of the Digital Mobility Strategy play an important role in this, aiming to create a comprehensive approach for sustainable and innovative mobility.

2.1 ITS strategy and ITS progress report (2016-2021)

With the Strategy for the Development and Implementation of Intelligent Transport Systems and Services (ITS) – the 'ITS Strategy for Hamburg' – from 2016 and the progress report on this strategy from 2018, Hamburg has demonstrated ways in which digital solutions can enhance traffic safety, reduce traffic-related environmental impacts, improve reliability and efficiency, and promote effective and safe information distribution as well as innovations.

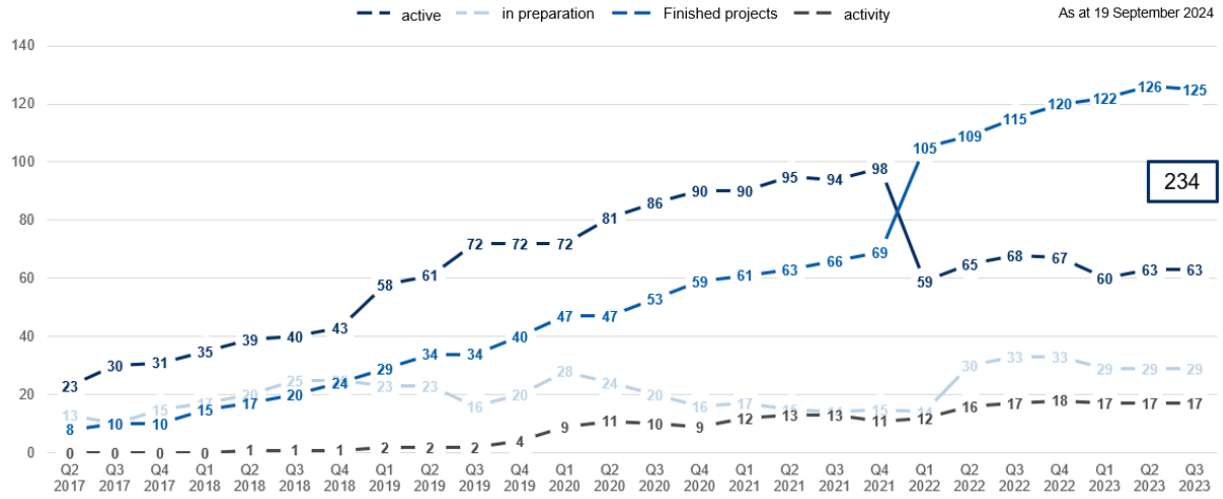

Figure 3: Number of ITS projects in the ITS dashboard (as at 19 September 2023)

At the end of 2021, the project portfolio comprised over 200 projects in which numerous new technologies and approaches were tested and demonstrated. The focus was on 42 anchor projects, which had a significant impact on achieving the objectives of the ITS strategy and formed an important basis for other ITS projects. The 200 ITS projects can be categorised into the six fields of action of the ITS strategy:

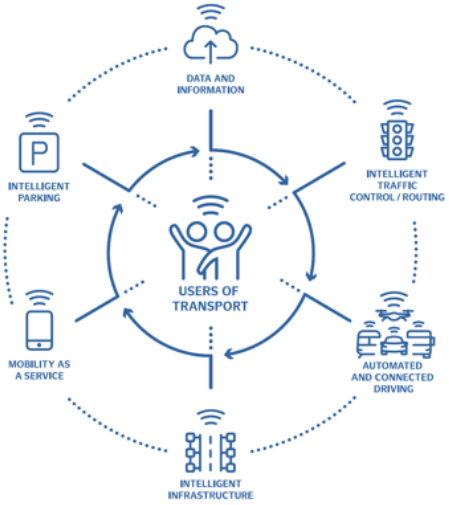

Figure 4: ITS strategy action areas

ITS World Congress 2021 in Hamburg

The ITS World Congress is the most important international event in the field of intelligent transport systems and services. Experts from the mobility, logistics, and IT sectors as well as representatives from politics and associations gathered in Hamburg from 11 to 15 October 2021. The conference was themed ‘Experience Future Mobility Now’. The host city welcomed over 13,200 participants from 66 countries, reaching a record number of 15,000 registrations. Almost 4,000 members of the public attended the Public Day with its own lecture programme, tours of the trade fair, and technical demonstrations. Highlights of the congress included the maiden flight of the cargo drone ‘VoloDrone’ at the ‘homePORT’ site, which was established by the Hamburg Port Authority (HPA) alongside the congress for demonstrations in the fields of Urban Air Mobility (UAM) as well as water and underwater drones. Other notable features included the Mobility Transition Tours, which showcased nearly 100 ITS projects across the city in four themed tours. Guided tours were offered in the exhibition area several times a day for both trade visitors and the interested public on Public Day. Another key element of the ITS World Congress was the ITS Summit, which brought together over 70 ministers, mayors, industry leaders, and senior representatives from national and local governments across more than 20 countries. They gathered to discuss how intelligent and eco-friendly mobility can contribute to sustainable growth and a better environment for people.

Figure 5: Impressions of the ITS World Congress 2021 in Hamburg © ERTICO

ITS networks and industry co-operations

Hamburg has been increasingly involved in national and international networks since 2016. This was made possible by incorporating Hamburg's ITS themes into numerous specialist events and actively participating in various committees, platforms, and working groups. Examples include the Mobility as a Service (MaaS) Alliance, the TM2.0 platform, which brings together private and public stakeholders in traffic management, the international and European ITS programme committees, and the national Digital Summit. Membership in the European ITS network, the European Road Transport Telematics Implementation Coordination Organisation (ERTICO), was particularly productive, because it allowed for the utilisation of a wide range of funding opportunities.

Since 2016, the industry collaboration has always been vendor and technology neutral, involving partner companies such as Volkswagen, Mercedes-Benz, BMW, Siemens Mobility, Deutsche Bahn, Continental, HERE, Deutsche Post/DHL, and Telekom. This collaboration was based on Memoranda of Understanding (MoUs) and included regular meetings. For example, the Volkswagen MoU facilitated the successful rollout of the fully electric ride-pooling service MOIA across the city, which is currently being further developed for autonomous operation until 2025. The deep integration of MOIA services into the urban mobility platform hvv switch is also part of the joint cooperation. Deutsche Bahn was able to launch the world's first regular operation of the Digital S-Bahn on the S2/S21 line. In addition to redesigning selected stations, they established an on-demand shuttle service. This service is now offered by Verkehrsbetriebe Hamburg-Holstein (VHH) under the name hvv hop, serving as a last-mile mobility system in selected city districts and the surrounding Hamburg area.

Hamburg for Digital Mobility Real-World Lab

In 2020, the RealLabHH was launched in Hamburg on the initiative of the National Platform for the Future of Mobility with a total of eleven sub-projects. Digital mobility solutions should be used to show how municipal transport systems can be made more sustainable, safer, more convenient, and more reliable as well as how their legal framework can be reviewed. This included testing a digital platform, autonomous driving, on-demand services, intelligent logistics solutions, collision warning systems, and a digital level crossing. The projects ran in both urban and suburban areas and included a dialogue strategy.

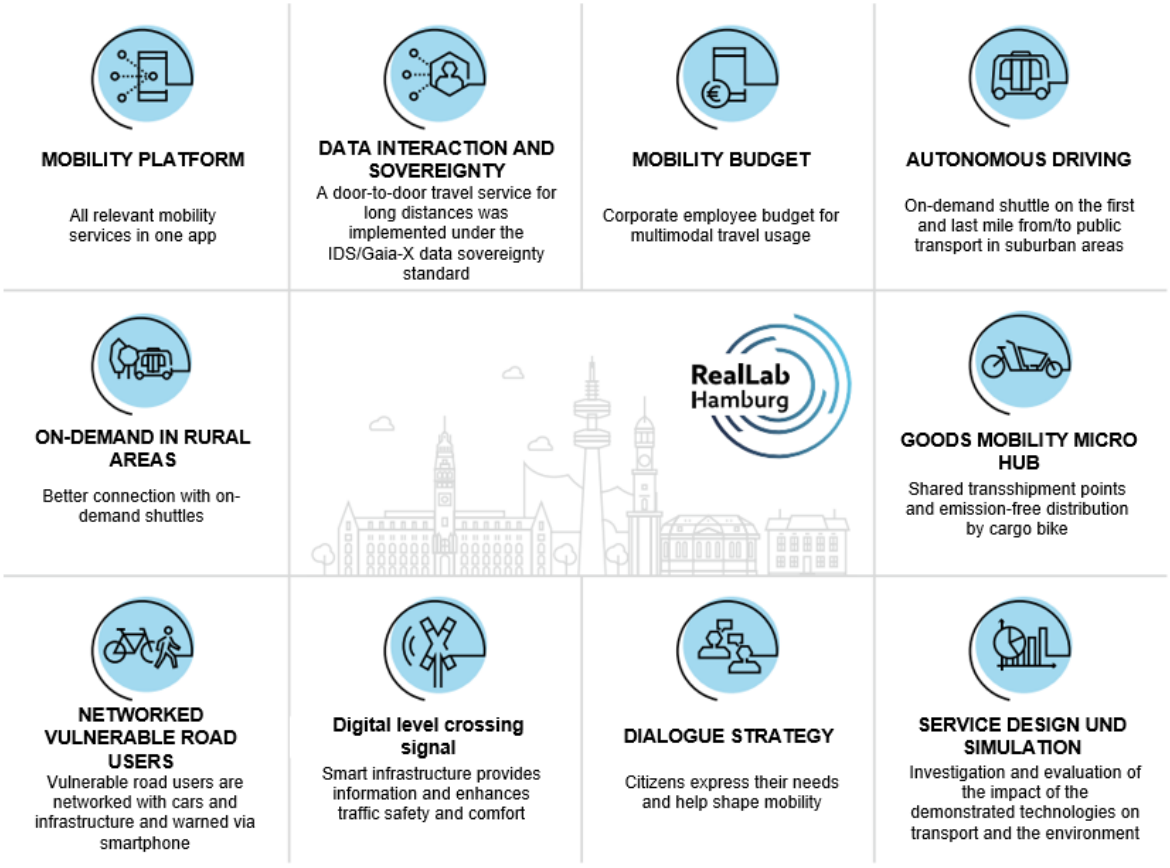

Figure 6: Project overview in RealLabHH

2.2 Lessons learnt from the ITS strategy until 2021

To evaluate the previous results and impacts of the existing projects in light of a further rollout, the project managers of the ITS projects were asked for their detailed assessments and recommendations from their respective projects after the ITS World Congress 2021 and into spring 2022. The results represent an important recommendation as to which projects should be scaled up from a technical perspective.

One of the key findings was the need for an overarching Traffic and Mobility Management System (MOS) that promotes the networking of urban control and operations centres as well as the exchange of real-time information. Another important aspect is the promotion of hybrid vehicle-to-everything (V2X) communication (ITS G5, 5G) for C-ITS services. This involves vehicles communicating with each other and/or with the traffic infrastructure, such as in the event of accidents, or emergency vehicles communicating with the traffic lights on a route to be travelled. These initial applications should be driven forward and expanded to ensure seamless networking of road users. The public Test Track for Automated and Connected Driving has been identified as an open test track for all users to trial innovative mobility solutions and, as recommended, should continue to be utilised. In addition, it was recommended that existing system architectures be used as a basis for further projects, such as in the case of BiDiMoVe (Bidirectional, Multimodal, Networked initiative). Predictive maintenance of buildings and transport systems is another important aspect of ensuring safe and reliable operational management. It was recommended that standardisation and harmonisation in the industry should be supported and promoted through participation in committees. Operating and installation costs should also be considered at an early stage as part of project management. The issues of data security and data protection must always be given high priority in order to ensure user acceptance. In the future, attention should be paid to providing data for use in regular operations and other projects free of charge and without discrimination. The continued use of the Public Key Infrastructure was considered a success factor.

An important insight into the status of the projects revealed that, despite external factors such as the COVID-19 pandemic, numerous projects in the field of intelligent transport systems were able to progress as planned. Of the 65 projects surveyed, 80 percent were implemented as planned. This demonstrates the community spirit and expertise of the ITS community, which continued to collaborate and integrate new technologies, partnerships, and innovations even during the pandemic. In retrospect, the ITS World Congress can be seen as a driving force for the ITS community, initiating and successfully implementing numerous projects.

A comprehensive infrastructure setup for autonomous driving by 2030 has become obsolete due to advancements in vehicle technology in this area. Autonomous vehicles now require minimal infrastructure support to perform their functions.

The objectives in some other ITS projects, on the other hand, have been exceeded. For example, in the Traffic Light Forecast (TLF) project, the number of nodes with intersection typologies (MAP files) provided via the Urban Data Platform Hamburg was exceeded (727 instead of 700). Further information on the individual project developments and lessons learnt can be found in the appendix.

3 Mission statement, strategic goals, and development paths

3.1 Target architecture of the Digital Mobility Strategy

Building on the success of the previously implemented ITS strategy and its updated version, this is being further developed under the name **Digital Mobility Strategy (DMS)** and is intended to be considered as a driving force of the mobility revolution. The following target architecture organises the DMS:

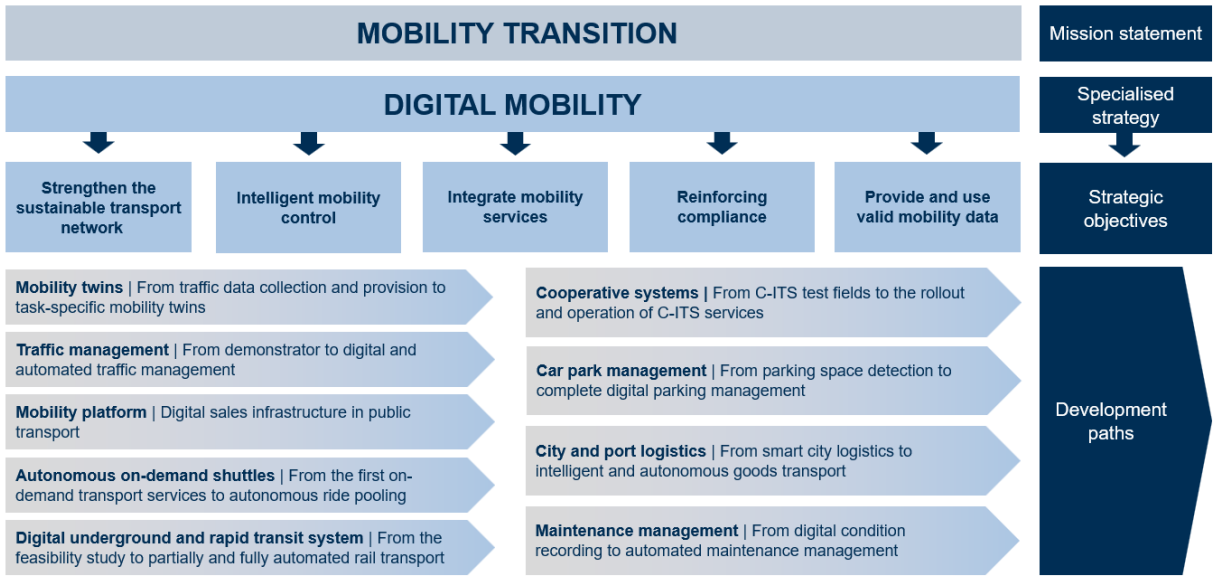

Figure 7: Target architecture of the Digital Mobility Strategy (DMS)

As a specialised strategy, the Digital Mobility Strategy is intended to support the mobility revolution through digitally connected mobility services and to strengthen climate protection goals. Central to achieving these goals, alongside the transition to alternative drives, is the 'modal shift' – a shift from journeys previously made by private motorised transport to modes of transport within the sustainable transport network, including public transport, walking, cycling, as well as on-demand and sharing services. The Senate's goal is to increase the share of journeys made using the sustainable transport network to 80 percent by 2030. Expanding the range of sustainable transport network is a key lever for achieving these goals. The expansion of services within the sustainable transport network is a key lever for achieving these goals. Hamburg will continue to rank among the leading European metropolises and drive this development with autonomous on-demand and mobility services from the sharing economy, taking into account the protection of vulnerable road users and complementing the public transport system.

The strategic objectives can be identified from the target architecture shown in Fig. 7. They tie in with the objectives of the ITS Strategy 2016. The aim is to achieve sustainable, efficient, and safe mobility for all road users. The strategic objectives interlock to enable a future-proof digitalised mobility that meets the needs of all users while simultaneously minimising environmental impact. The following objectives should be taken into account for the Digital Mobility Strategy when planning and implementing future digital projects and digital activities in the mobility sector:

Strengthening the sustainable transport network

- Improve the interaction between modes of transport in the sustainable transport network in order to promote the use of intermodal transport chains.
- Utilise new technological approaches and mobility solutions in public transport, such as emission-free and highly automated vehicle fleets in regular operation.
- Operate the first section of the U5 fully automatically, run sections of the U2 and U4 partially automatically, and increase the use of fully automated vehicles in the Hamburg S-Bahn network.
- Rail-based transport infrastructure is to be planned, built, and operated using the latest digital modelling technologies.
- Adapt bus priority technology at traffic lights in order to increase the attractiveness of public transport by shortening journey times and dynamic, demand-based prioritisation.
- Improve the planning of cycling and walking infrastructure through additional traffic data.
- Digitally increase the attractiveness of walking and cycling by providing analogue and digital services.
- Introduce new services such as ride sharing and pooling.
- Provide mobility-impaired individuals with solutions in public spaces, local transport, and through digital services that enhance their participation in daily life and transport.

Intelligent mobility control

- Establish and utilise an overarching, multi-modal smart traffic management system to manage disruptions to planned mobility capacities, such as traffic disturbances.
- Incorporate predictable events accurately and timely into traffic management and differentiate traffic volume in real-time by traffic types and individual lanes.
- Digitally network control centres and operations centres for active responses to traffic situations and for a cross-modal, proactive information management system.
- Shift and avoid traffic by providing real-time information and implementing targeted traffic control measures to reduce peak traffic periods.
- Check the prioritisation of buses, cyclists, and pedestrians in the traffic light control system.
- Provide the respective signal colours of the traffic lights also via digital communication channels.
- Provide mobility-impaired individuals with solutions in public spaces, local transport, and through digital services that enhance their participation in daily life and transport.

Integrate mobility services

- Operate and further develop a comprehensive, multimodal, user-centred digital mobility platform to provide information on intermodal and multimodal transport options across different providers, enabling cross-provider planning, booking, and payment.
- Public (hvv, HOCHBAHN, VHH, DB, etc.) and private providers (car, bike, and ridesharing, taxis, e-scooters, etc.) are cooperating to increase the attractiveness of public transport.
- Connect the digital services for car park management with the hvv switch mobility platform and integrate them into it.
- Reduce barriers to accessing traditional public transport through digital sales.

- Provide mobility-impaired individuals with solutions in public spaces, local transport, and through digital services that enhance their participation in daily life and transport.

Improve compliance with regulations

- Test and roll out safety-relevant Cooperative Intelligent Transport Systems (C-ITS) services, such as traffic jam warnings or red light violation warnings (see also 3.2.6 ‘Development Path for Cooperative Systems’).
- Better protect cyclists and pedestrians at intersections through the use of digital and analogue services.
- Utilise static and dynamic traffic data to increase the road safety of vulnerable road users.
- Enable the transport infrastructure to communicate directly with road users.
- Digital and automated car park control.

Provide and use valid mobility data

- Identify the need for traffic data for C-ITS applications and services.
- Publish mobility and traffic data via the urban data platform (UDP) and/or the Federal Mobilithek for internal and external users without discrimination, provided that data critical to privacy or security is excluded.
- Ensure the data quality and data availability of all published data sets, taking into account relevant use cases.
- Formulate meaningful metadata information to ensure the applicability of the published data.
- Develop the Hamburg Mobility Twin, which consists of various task-specific mobility twins, to enable its use for a wide range of applications.
- Broaden and improve the database in the area of walking and cycling as well as micromobility and intermodal transport.
- Increase the usability and degree of utilisation of existing data (models).

3.2 Development paths

Derived from the strategic goals, nine development paths are illustrated on a graphical timeline, showing how the goals can be achieved through specific measures, projects, or activities. Some projects have already been successfully completed and are in operation, many projects are currently being implemented, and others are planned and will be rolled out subsequently to create sustainable, efficient, and safe mobility for all. The following categorisation distinguishes the respective project status:

Figure 8: Legend of the project development paths

Following the respective timelines, the development paths are presented. The main areas of action up to 2030 are presented in bullet points, followed by a description of the development path. User journeys are used to illustrate the possible experiences that typical individuals may have throughout the entire process of using digital mobility services. This helps to better understand the users' needs and identify how digital mobility can be tailored to meet these needs in the future.

3.2.1 Development path for mobility twins

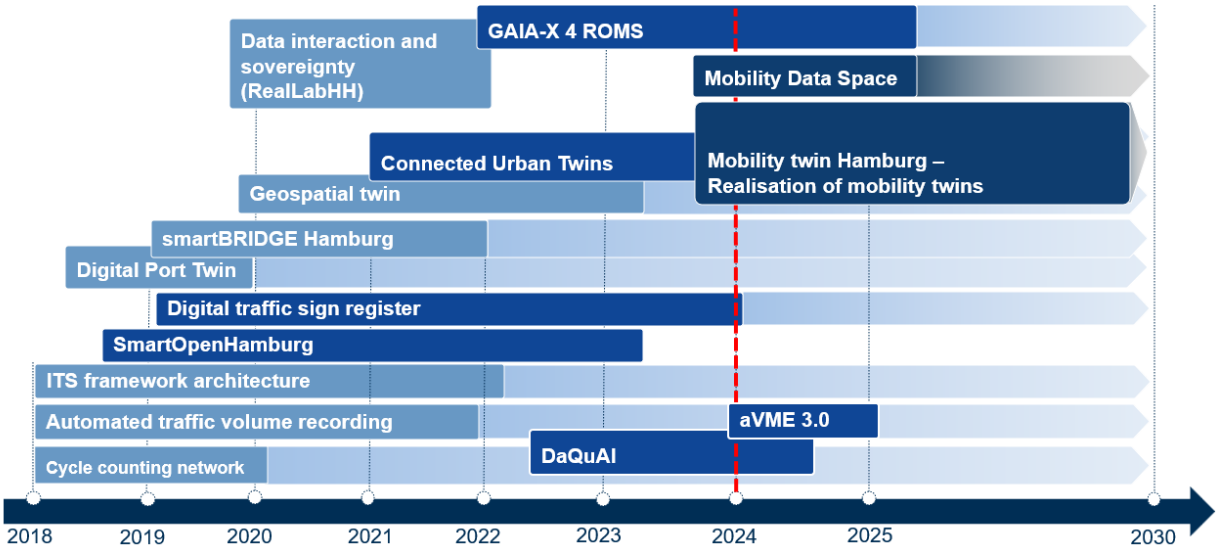

Figure 9: Development path for mobility twins | From traffic data collection and provision to task-specific mobility twins

Key focus areas 2030

- Comprehensively collect mobility data digitally and make it available via local, national, and European platforms as open data in a non-discriminatory manner.
- Determine and optimise data quality and define and guarantee data availability using an AI-based approach.
- Develop mobility twins and their instances based on geo-base twin components, specialised data, simulations, and applications, and consolidate them in a catalogue called the 'Hamburg Mobility Twin'.
- Use digital mobility twins across the board, such as for strategic traffic planning and operational traffic management.

Description of the mobility twin development path

The development path for mobility twins involves the transparent and standardised collection of mobility data and its provision to make it usable in task-specific mobility twins over the coming years.

Experience from projects involving the development of digital twins can be utilised in this process. The framework infrastructure for digital twins in Hamburg is provided by the urban data platform (UDP) in conjunction with the Free and Hanseatic City of Hamburg GeoPortal. A wide range of specialised, planning, and real-time data from across the Free and Hanseatic City of Hamburg have been consolidated on the Urban Data Platform. The detailed maps available in the geo-base twin, together with high-resolution aerial images, and the 3D model of the city, give this data the necessary spatial reference. Specific specialised twins can be created for various applications in the fields of urban development, environment, mobility, and more using these basic services. Initial specialised twins have already been developed in Hamburg through projects such as SmartOpenHamburg, Digital Port Twin, RealLabHH (TP2), and smartBRIDGE. These digital twins were developed to explore specific aspects related to predictive information and decision support systems for individual and multimodal mobility and logistics in Hamburg. A demonstrator was developed in the Hamburg real-world lab to enable

networking and cooperation between several partners and regions. A multiple (international) award-winning pilot project of a digital twin is the HPA project smartBRIDGE, which optimises the maintenance of the ageing Köhlbrand Bridge in the Port of Hamburg using a digital twin (see development path maintenance management, chapter 3.2.9). This project serves as a blueprint for the development of digital twins for bridge structures in the federal highway network and was published by the Federal Department of Transport and Digital Infrastructure in the document 'Digital Twin of Bridges – Contribution to the Master Plan Digital Twin Federal Highways' (Link). Alongside this, an interactive real-world lab demonstrating the functions of the digital twin on the Köhlbrand Bridge was launched by the Federal Department of Transport and Digital Infrastructure and BIM.Hamburg. (Link). The developments emerged through close cooperation between the Federal Department of Transport and Digital Infrastructure and BIM.Hamburg, and specifically demonstrate what innovative and predictive maintenance management of the future can look like.
The Hamburg mobility twin covers the topic of mobility and represents a collection of all task-specific mobility twins. In addition to mobility data, a mobility twin also incorporates services (such as analysis or simulation algorithms) and additional data from other fields to address a specific application. The knowledge gained is used to control and optimise transport in the city. A task-specific mobility twin can therefore be an application for improving and optimising traffic planning or traffic management.

Figure 10: Control cycle of the Sharing Mobility specialist twin

The task-specific mobility twins can exchange information via standardised interfaces and be networked with each other. The overall view of all task-specific mobility twins can be described as the 'Hamburg mobility twin'. The Mobility Twin Hamburg plays a special role within the context of the Digital Mobility Strategy, serving as a central and accessible point for the provision and visualisation of mobility data. It forms an important foundation for all other development paths within the Digital Mobility Strategy.

In recent years, Hamburg has placed a particular emphasis on the collection, publication, preparation, and visualisation of data. This has included projects for recording traffic infrastructure such as the digital cycling network and the traffic sign register, projects for publishing infrastructure condition data like traffic light signal statuses or occupancy information of electric charging stations, as well as projects for traffic counting, such as automated traffic volume recording (aVME, counting of motor vehicles) or the cycling traffic counting network (HaRaZäN) built with the same technology.

Collecting valid mobility data and providing it through the concept of the ITS framework architecture in Hamburg's urban data platform has been and continues to be an important step towards creating sustainable and future-proof mobility. Until a few years ago, the focus was primarily on counting motor vehicle traffic. It was only in the last five years that a systematic approach was taken to validly and comprehensively record cycling traffic. The insights are utilised by authorities to undertake more targeted street and cycle path planning and to implement measures to improve traffic flow and safety more effectively. The aim for the coming years is to stabilise the automated counts and increase data availability and data quality. The city's geoportals, such as the transport portal, are used to prepare and visualise the data.

Another important goal in the course of the development path is to create and establish interfaces to new data hubs. In addition to the Hamburg urban data platform and Mobilithek platforms already in use as a national data access point, the aim is to create access to new mobility data spaces that ensure the sovereignty of the data and offer opportunities for new types of services. Noteworthy in this context are the Mobility Data Space and the ROMS data space of the Gaia-X 4 ROMS project (Remote Operation for Automated and Connected Mobility Services), which follow the cloud-based Gaia-X concept. This concept of a new cloud infrastructure is also supported by the development of European standards by Hamburg.

The State Traffic Authority provides the following geospatial datasets for digital twins in car park management: public car parks in selected districts, the locations of parking meters, and resident parking and special management zones. Further data sets are in progress.

In the project 'Connected Urban Twins: Urban Data Platforms and Digital Twins for Integrated Urban Development' (CUT Project) (see info box), the Free and Hanseatic City of Hamburg is advancing the development and application of digital twins in collaboration with the cities of Munich and Leipzig. One result of the CUT Project will be a DIN specification (DIN-SPEC 91607: Digital Twin for Cities and Municipalities), which will describe a standardised modular system for creating urban digital twins for integrated urban development. Federated mobility twins, such as the Mobility Twin Hamburg, can also be developed on this basis.

This DIN specification will also outline quality standards for the use of data in urban digital twins to ensure accurate and reliable operation. An important aspect in the assessment of data quality is the distinction between self-produced and refined data. In the future, it will be increasingly important to make a clear distinction between these types of data to ensure that the data is used appropriately.

Info box

The Connected Urban Twins project and the definition of urban digital twins

In the Connected Urban Twins project: Urban Data Platforms and Digital Twins for Integrated Urban Development (CUT), a framework for the operationalisation of Urban Digital Twins is being designed and implemented. The essential basis of an urban digital twin of a data-sovereign city is its urban geodata. This geodata defines the spatial reference, enables a persistent, interdisciplinary information link and thus creates a clear interpretation space. The compilation of all urban geodata resources can be summarised as a geodata twin.

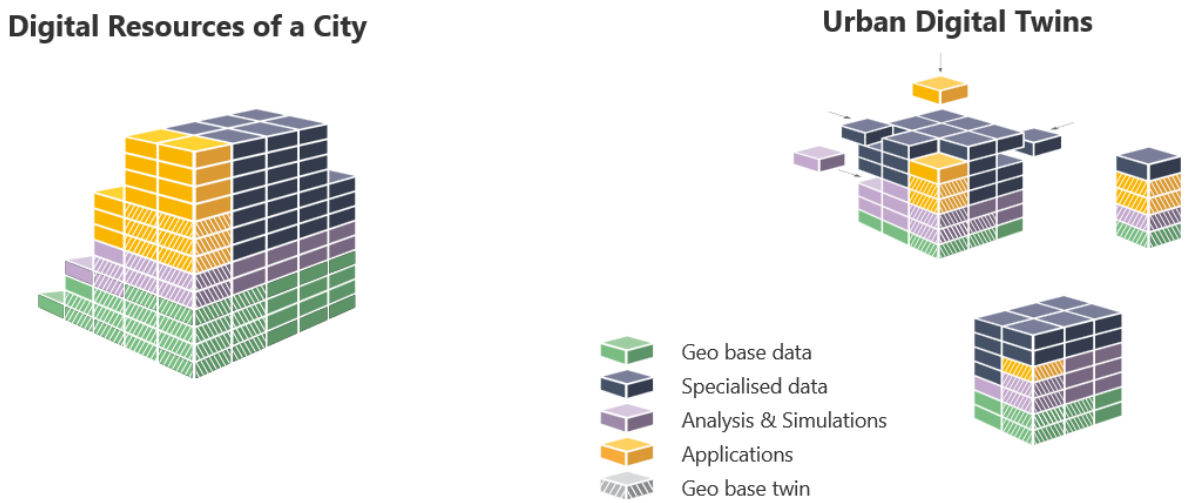

Figure 11: Conceptual structure of the urban digital twin according to CUT project (Schubbe et al. 2023)

Building on a unified geospatial twin, a digital mobility twin can reliably address specific mobility issues using data. It takes into account not only specially collected data but all available data. Mobility twins are therefore urban digital twins on the subject of mobility and transport. Because the topic is wide-ranging, there can be several task-specific mobility twins that answer different questions. These twins are composed of a city's digital resources (geospatial data, specialised data, analyses, and applications), which vary depending on the use case. Additionally, parts of the geospatial twin are integrated into these task-specific mobility twins.

A particular challenge is always the updating and maintenance, and thus ensuring the quality and currency, of the collected data, which is essential for use in a mobility twin. This will be one of the main focuses of our work over the next few years. For example, the recorded motor vehicle or bicycle traffic volumes should be checked for plausibility before publication and use. In addition, a follow-up project on automated traffic volume detection is being developed to explore possibilities for even more efficient operation and to ensure data is kept up to date more effectively.

Further mobility twins will be developed in the coming years based on components of the geospatial twin, specialised data, simulations, and specialised applications. These will address questions in the transport sector comprehensively and provide a better understanding of traffic flows and patterns. At the same time, standardised digital mobility twins enable the reproducibility of results, allowing for comparisons of simulation or study outcomes based on identical mobility data. At the end of the development process, digital specialist twins can be used to support decisions relating to the planning and control of the transport system.

Fictitious user journey 2030 - mobility twins

- Johanna Sommer is a transport planner at the transport authority and can use digital mobility twins on her computer. Through the transparent collection and standardised provision of connected mobility data under the umbrella of Hamburg's federated mobility twin, Johanna now has 'one-click' access to real-time information on all geo-referenced facts relevant to her tasks from a single source. With the available and up-to-date data from the bicycle traffic counting network and the capability to simulate traffic flows, as well as the high-resolution road database, she can plan Hamburg's cycle paths in a targeted and efficient manner, aligning the expansion with the needs of the users. She knows where cyclists are travelling and can match these findings with the existing cycling infrastructure. She can also use simulations to assess the impact on traffic flows, emissions, and road safety before the measures are implemented.

- Konstantin Krämer is a student at a Hamburg university. He often has to work with data and answer scientific questions as part of his studies. The city's Urban Data Platform provides him with a wide range of up-to-date data for his projects, which he can use to answer statistical questions very quickly or create maps with the available geodata. The open accessibility simplifies his work, allowing his inquiries to be aligned with the reality in Hamburg.

- Paul Kleinfeld is an employee of the Hamburg Transport Authority and works with mobility twins. His focus is on the implementation of road traffic measures. When major events take place in Hamburg, he can simulate the effects on traffic flow in advance. Paul meets with the police traffic department before the events and discusses how visitors can be routed collaboratively at the next major event. This worked brilliantly for the first time at the 2024 European Football Championship. This means that diversions for motorised private transport and public transport can be announced to all visitors via the ticketing system long before the event. For visitors and everyone else travelling in Hamburg, this means less stress and transparent information, for example about changes to timetables. But Paul can also respond more quickly to spontaneous incidents based on data and make AI-supported decisions.

- Bodo Hoffmann commutes by car. Since the city collects a wide range of traffic data, uses it in the mobility twin for parking and also makes it available to third parties, his sat nav provider can access it and create the best and fastest route in real time. Bodo's navigation system even guides him directly to a park-and-ride (P+R) car park in the event of a very rare disruption, such as a major roadworks site, so that he can get to his workplace more quickly.

3.2.2 Traffic management development path

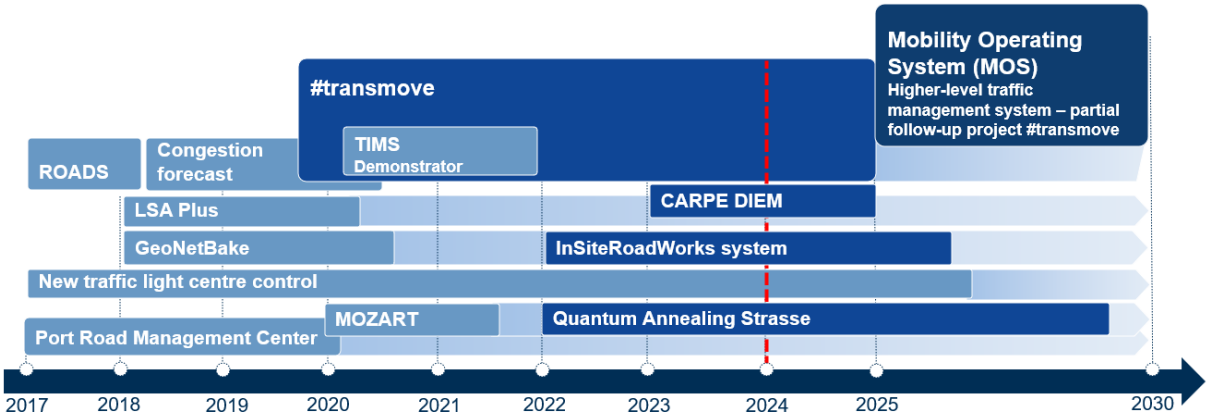

Figure 12: Traffic management development path | From demonstrator to digital and automated traffic management

Key focus areas 2030

- Applying various technologies to collect traffic data, present and share information, simulate scenarios, forecast developments, and (partially) automate traffic management interventions.
- Use a Mobility Operating System (MOS) (possibly subdivided into several services) across all modes of transport to bundle the most important transport information.
- In the event of unforeseen incidents, implement scenario-based traffic management to receive ad hoc action recommendations and, if necessary, (partially) automate traffic control interventions.
- Establish new traffic computers and a modernised central traffic light control system as the core of traffic management and make traffic light signals (such as for cycling app solutions or V2X applications) available digitally.
- Deploy more than 1,000 geo-referenced beacons on the construction sites of the State Office for Roads, Bridges and Waterways (LSBG).

Description of the traffic management development path

The traffic management development path ‘From demonstrator to digital and automated traffic management’ describes the use of technologies to optimise traffic flow. The demonstrators of such technologies have been developed and tested in numerous ITS projects in recent years. The existing system is being gradually replaced, establishing a foundation for cooperative systems (C-ITS). One of the development path’s goals is to gradually establish a Mobility Operating System (MOS), potentially divided into multiple services, which consolidates key traffic information and provides users with scenario-based action recommendations.

Pioneering measures in traffic management have been created through Traffic Light Plus, among other things, by reducing pollution through sustainable stop-and-go traffic control (green wave) at traffic lights. Information from all traffic lights and other traffic detectors can be bundled into one smart system with the new traffic light centre control system. The traffic flow can be analysed and controlled as a whole and disruptions can be responded to more quickly. The congestion forecast also allows proactive traffic management to reduce congestion. The GeoNetBake project allows construction sites to be georeferenced and displayed using GPS sensors in construction barriers. Before a city-wide rollout, all system requirements are verified once again in terms of functionality and quality in the complex environment of selected major construction sites, and potential for improvement is identified and utilised. Once the regular operation of digitally mapping realistic construction site polygons is secured, the rollout will see

the deployment of over 1,000 smart barriers in the coming years. These barriers will provide lane-specific, real-time updates on the traffic impacts of construction sites and supply the relevant data.

The Port Road Management Center facilitates integrated traffic situation displays, such as digital information boards known as DIVA boards and manages lorry parking in the port.

Ahead of the ITS World Congress 2021, a Traffic Information Management System (TIMS) was tested as part of the #transmove project to enhance connectivity between operational control and management centres. The currently active #transmove project builds on the Traffic Congestion Forecast project to develop an AI-supported mobility forecast, providing decision support for comprehensive traffic and mobility management. The target and user groups of this decision support system include operational traffic management control centres, urban construction coordinators, traffic planners, and the general public.

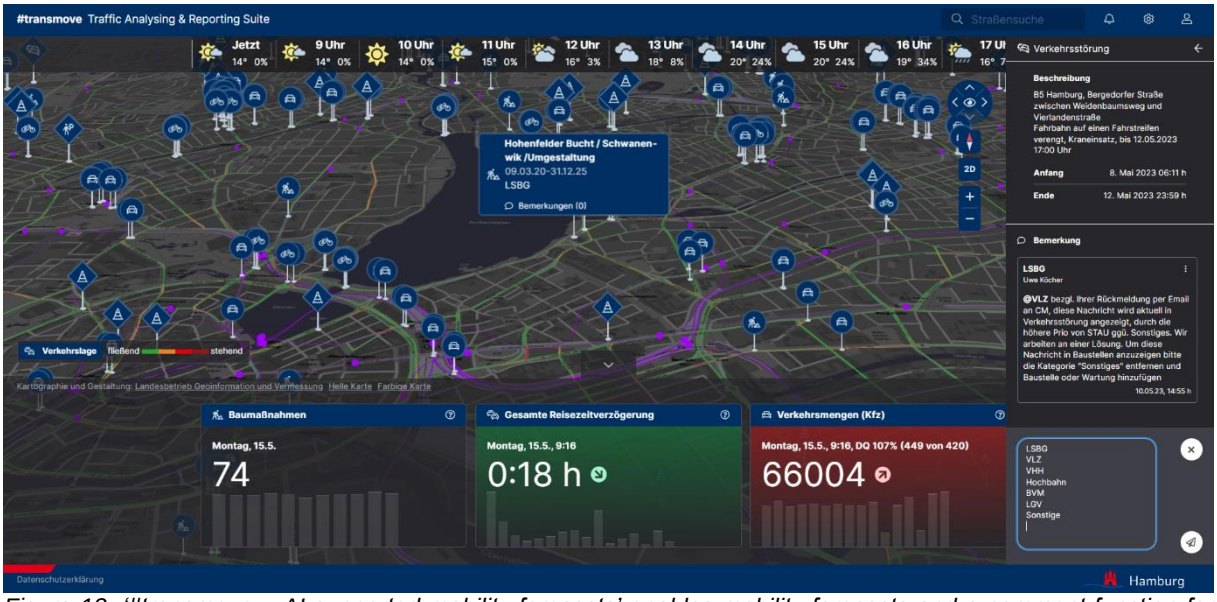

Figure 13: '#transmove – AI-supported mobility forecasts' enables mobility forecasts and a comment function for ad-hoc traffic planning based on the mobility dashboard

Based on the #transmove project currently running in the State Office for Roads, Bridges and Waterways, the MOS will in future combine the various urban specialist applications and subsystems of the operational traffic and mobility management. The aim is to provide a common basis for decision-making for all urban control and operations centres, real-time information exchange, and a 'toolbox' for early scenario-based recommendations for action. These scenario-based recommendations for action are to be implemented by the MOS as automatically as possible and in line with the European data strategy.

Excursus | Mobility in the third dimension – Urban Air Mobility (UAM) and drones in Hamburg

Hamburg recognised the potential of drones and other air mobility applications in the field of Urban Air Mobility (UAM) for industry and urban society as well as public authorities and state companies at an early stage. In addition to promoting the Windrove network initiative founded in 2017, the city is actively involved in numerous research and development projects, innovation activities, and committee work at local, national, and European level. Based on this comprehensive understanding of the opportunities and challenges of drone applications in an urban context, the city is actively shaping this topic and its own role as one of the first European model cities for Urban Air Mobility (UAM) in collaboration with numerous partners from business, academia, and politics. The promotion of a sustainable UAM ecosystem is essentially based on three pillars: legal framework, technology, and social acceptance. In 2023, Department of Economics and Innovation launched a comprehensive strategy process together with Windrove, including relevant acceptance and environmental issues. To gain a comprehensive understanding, it is important to differentiate between the perspectives of economic promotion and industrial UAM developments at the aviation hub Hamburg on the one hand and the integration of drones into air traffic as well as the use of drones in Hamburg on the other. During the ITS World Congress 2021, several flagship projects focused on drones were presented and demonstrated to great acclaim: Medifly-Hamburg (drone transport for medical purposes), FALKE (drone detection and defence), HHLA Sky Control Centre and UDVeo (drone traffic management), AI Inspection Drone (AI-controlled aircraft inspection), i-LUM (comprehensive approach to urban air mobility), and the VoloDrone (heavy-lift drone). Since then, the Hamburg project landscape has grown to over 20 active and pending Urban Air Mobility projects (as of January 2024). The entire spectrum of drone applications, system and technology innovations, as well as legal issues are considered (see figure).

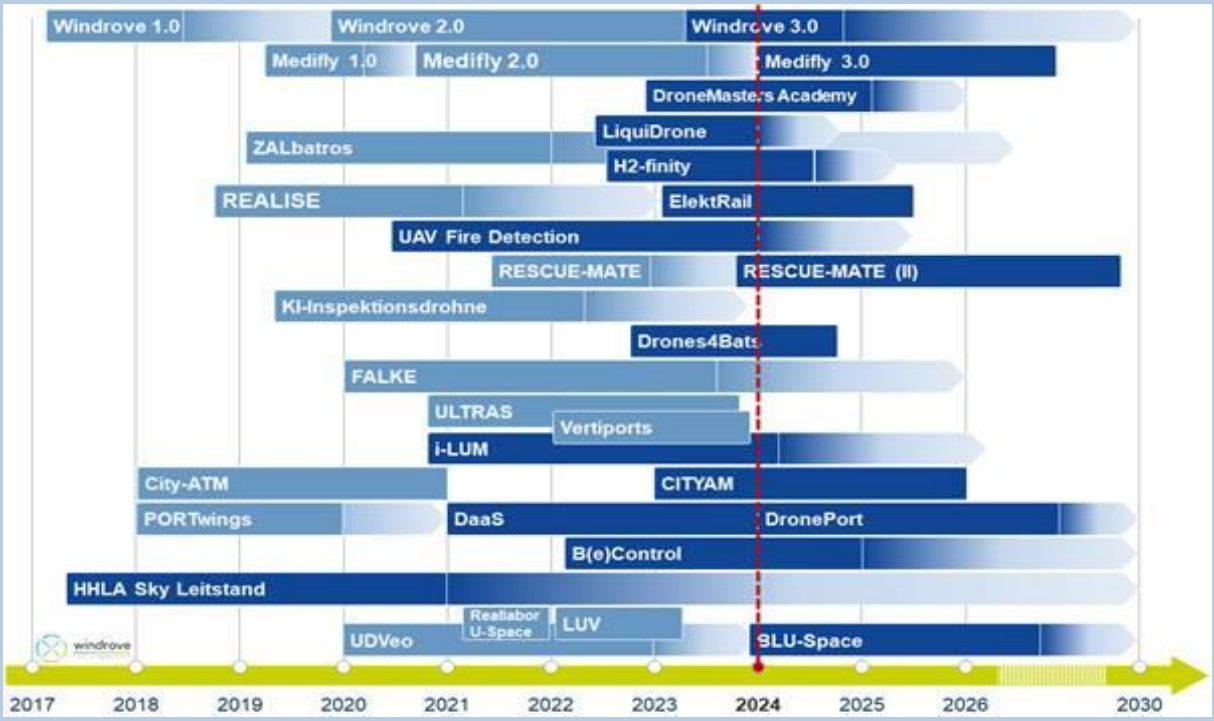

Figure 14: Hamburg urban air mobility projects and activities

One of the key focuses is on the traffic management of drones. To ensure the safety of a multitude of unmanned drone flights in lower airspace in the future, not only are special traffic regulations, for which there is now an EU-wide framework, required, but also a separate digital traffic management system will be needed. This system will facilitate the regular use and application of drones in Hamburg (for example, in the Port of Hamburg area). However, it is currently still in the process of legal, technical, and organisational development, with many questions yet to be answered. The development of an air traffic management system for drones

and the alignment of ground traffic management for various mobility forms in line with this strategy are currently running in parallel. An intermodal connection of traffic management systems is desirable in the long term.

Further information can be found in the Department of Economics and Innovation's handout on the 'Use of drones':
https://www.hamburg.de/contentblob/17861804/63739489badfea2d0bd716a4e608002c/data/handreichung-bwi-zu-drohnen-13-12-2023.pdf

Fictitious user journey 2030 – traffic management

Sofia Rodriguez works with the MOS in 2030 together with her team in the urban control and Operations Centres for Operational Traffic and Mobility Management. The shared decision-making framework makes it easy to identify disruptions and interferences with the use of AI, providing proposed decisions and solution strategies. Sofia can already simulate the impact of construction sites on traffic flow in advance and coordinate additional construction measures. The police, Hochbahn, S-Bahn, and VHH control centres can react more quickly in the event of disruptions and traffic flow can be improved. Sofia's team can promptly adjust traffic light sequences and provide comprehensive information to road users. Disruptions can be recognised at an early stage and largely automatically adjusted across all modes of transport. The shared basis for decision-making and the real-time exchange of information improve day-to-day work and reduce stress for everyone involved in the decision-making process.

3.2.3 Mobility platform development path

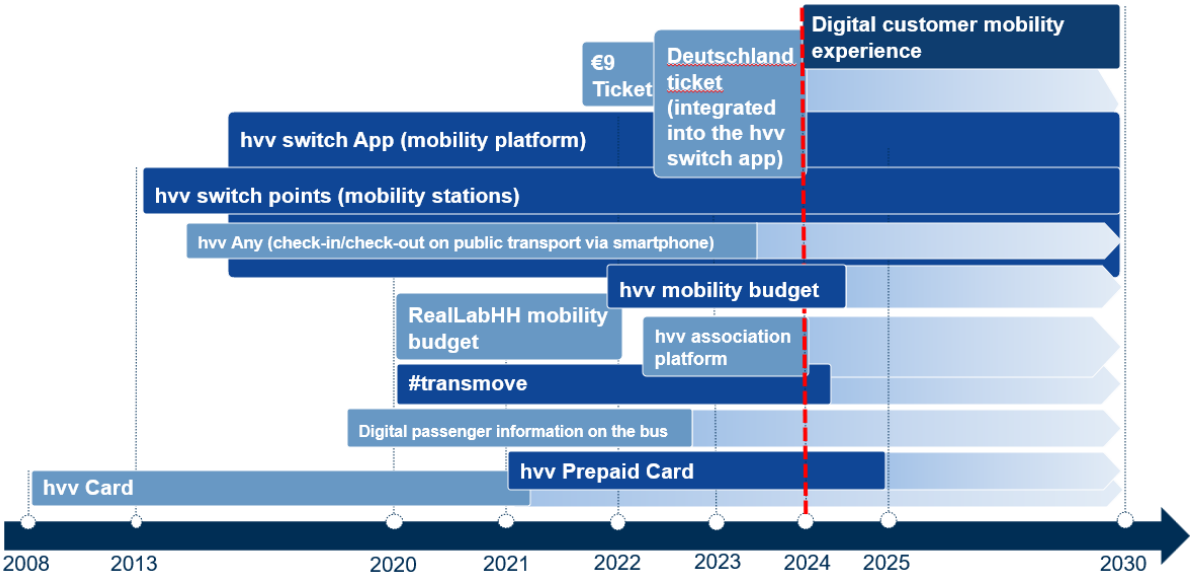

Figure 15: Mobility platform development path | Digital sales infrastructure in public transport

Key focus areas 2030

- Fully integrate additional relevant mobility providers into the hvv switch mobility platform.
- Expand and extend mobility stations, known as hvv switch points.
- Create a fully digitalised, user-centric, and simple mobility experience with one service.
- Integrate multimodal information with attractive intermodal route chains and further develop the Deutschlandticket and the mobility budget in the hvv switch app. For routing, consider professional and personal preferences for the selected means of transport and the technical concept.
- Make real-time information about disruptions and alternatives available in the app and on digital passenger information systems, ensuring accessibility for all users. The app can be customised to individual preferences regarding mobility options and more.

Description of the mobility platform development path

The development path for digital sales infrastructure in public transport refers to the digitisation of booking processes, passenger information, and the integration of various mobility providers into the mobility platform of the Hamburg Transport Association (hvv). The aim is to consolidate all information about all modes of transport in Hamburg onto a single mobility platform and make it available to users through an app, which can also be used for bookings. This should make intermodal mobility much easier for users. A major and probably the most significant revolution in public transport ticketing to date is the Deutschlandticket, which has been available to buy digitally or as a chip card since May 2023. Booking journeys on traditional public transport has thus become much easier for all users.

A standardised card had already been created in Hamburg with the introduction of the hvv Card, which enables e-ticketing in the entire hvv network. The classic hvv Card (including photo) has been replaced by the Deutschlandticket, with a few exceptions (school tickets in the surrounding area). The existing hvv Cards, which were automatically converted to the Deutschlandticket, were replaced during 2023 with nationwide-verifiable chip cards in the hvv Deutschlandticket layout. For anyone who does not have or does not want to use a smartphone, the hvv prepaid card will be a good alternative to cash for buying tickets on buses.

Another important element of the digital sales infrastructure is a powerful mobility platform. The hvv switch app accesses the platform's data and offers users and visitors a simple, fast, and convenient way to book their favourite mobility option in Hamburg, whether it's a shared ride

or public transport (including the Deutschlandticket). In addition to the existing Google Maps integration, intermodal information will also be offered in the hvv switch app in the future. Both professional and personal preferences in the chosen mode of transport are taken into account, as well as the technical design, while consistently pursuing the path towards an integrated mobility offering.
At hvv switch points, users can access various means of transport such as car sharing vehicles, e-scooters, and a connection to traditional public transport in one place. These can be easily booked with the hvv switch app. The expansion of switch points and the comprehensive integration of mobility providers aim to create a connected and simplified use of intermodal mobility chains. By deploying fully electric ride-pooling vehicles from MOIA and integrating car-sharing providers (including MILES and SIXT share), micro-mobility providers (TIER, Voi), and soon StadtRAD bicycles, the attractiveness and usability of multimodal public transport will be further enhanced, reducing the reliance on private cars.
The mobility budget successfully tested in RealLabHH is now already part of hvv switch. Employees receive a mobility budget from their employer through 'hvv M', which they can use for their preferred mode of transport, whether it's a sharing service or public transport. This budget can be used for private and professional mobility and is intended to offer an alternative to the use of a company car or private car. With the 'Check-in/Check-out' system from hvv Any, occasional users can conveniently check in for their journey using their smartphone without needing to know the fare details, ensuring they are charged the best possible rate for their trip. hvv Any was to be integrated into the hvv switch app in 2023. Whether the hvv-switch system will be further developed alongside the established hvv app in the future and whether both apps will continue to exist is being examined.
Since 2020, digital passenger information systems have been installed in some buses, trains, and ferries of the HVV, and will be included in all future vehicles. These systems provide travellers with important information such as transfer connections and announcements during their journey. In the future, all mobility services will be integrated into the hvv switch app to facilitate the organisation of multimodal journeys within a single application. The hvv network platform will enable the digitalisation of functions such as data analysis and dashboards. This will allow for anonymous analysis of user behaviour, thereby enabling demand-based improvements to services and offerings. It ensures that transport companies, responsible authorities, and the network itself can better convince more residents and visitors of the benefits of public transport and make it more attractive.
To enhance overall urban mobility, an intuitive AI-supported application called #transmove is being provided to mobility planners and the residents of Hamburg. Using agent-based modelling and machine learning, it delivers both long-term and short-term mobility forecasts through user-specific interfaces. The aim of the project is to effectively support mobility decisions and serve as a cornerstone of smart intermodal mobility management in Hamburg, which takes into account public transport, cycling, and motorised individual traffic.

Fictitious user journey 2030 - mobility platform

- Ida Anderson reaches for her smartphone in the morning to plan her routes for the day. The hvv switch app makes it easy to make reservations and bookings for different modes of transport without having to worry about tickets or timetables. The weather forecast is factored into their daily planning by networking the traffic management systems. She starts the app and selects her destination. The app automatically calculates the best and most suitable route for her and offers various options, including car sharing, ride sharing, e-scooters, rental bikes, or traditional public transport. Since the sun is shining today, Ida opts for a combination of a rental bike and the S-Bahn to get to her workplace.

- Lasse Larsson doesn't like cycling that much and prefers to walk a few metres to the nearest bus stop. His app recognises his needs and can suggest suitable routes to Lasse

accordingly. Today, he walks 300 metres to the nearest S-Bahn station and travels from there to the main station. Yesterday, it was suggested that he book an autonomous shuttle to get to work dry in the rain. The booking and payment for the on-demand shuttles integrated into public transport were seamlessly handled through the hvv switch app. Lasse travels from stop to stop very conveniently and at a low surcharge. Both are often only a few metres away from the actual start and finish. In bad weather, Lasse sometimes books a car-sharing vehicle via the hvv switch app. When he parks the vehicle at a switch station and changes to public transport, the central transport app (e.g. hvv switch app) informs him in real time about current disruptions and the reasons for them.

- Ida and Lasse receive monthly mobility budgets from their employers. These allow them to make business and private journeys without having to pay for them financially. These budgets can be easily used via the hvv switch app, allowing the two of them to travel flexibly and multimodally in Hamburg and the hvv area every day without the need for a company car or their own vehicle.

- Erna Maria Johannsen retired last year and does not own a car. Since she doesn't use her smartphone all the time, she likes to use the Deutschlandticket as a chip card to travel by public transport in Hamburg and the surrounding area. Because there is a mobility option within five minutes and the hvv switch app is easy to use even for older people, she no longer needs to have timetables in her head. One important aspect for Erna is accessibility when using public transport. She prefers real-time information about disruptions and alternative means of transport on the digital passenger displays at the stops, in the buses, and (autonomous) shuttles. They enable her to know exactly when she will arrive or if there are any delays, even without checking her smartphone.

3.2.4 Development path for autonomous on-demand shuttles

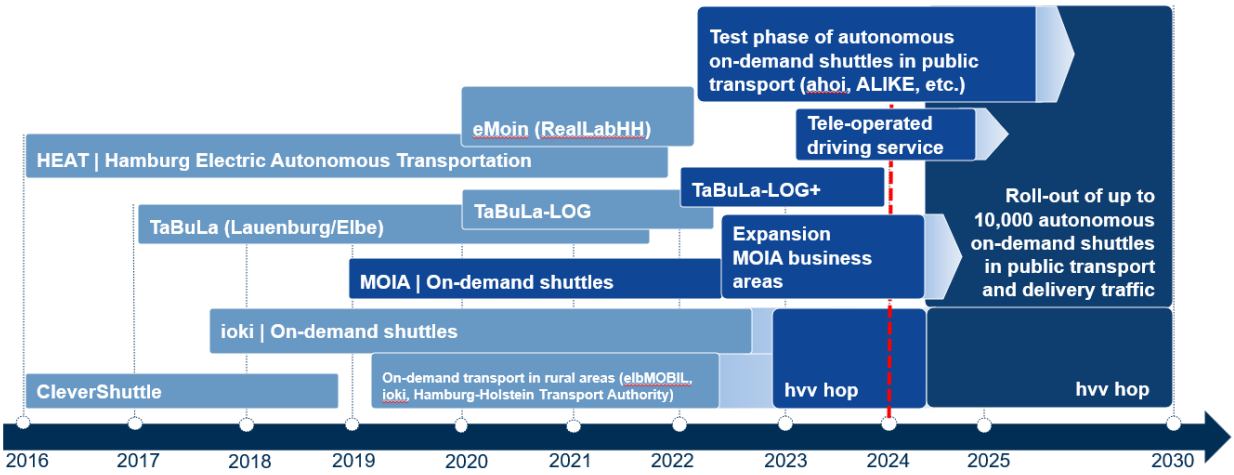

Figure 16: Development path for autonomous on-demand shuttles | From the first on-demand transport services to autonomous ride pooling

Key focus areas 2030

- Transform existing ride-pooling services within the Hamburg-Takt (plan to provide public transport within five minutes for all residents) into a large-scale, largely automated, and driverless system.
- Introduction of a digital system to manage operational areas for autonomous driving functions, including authorisation to monitor operations.
- Increase user acceptance of autonomous driving by ensuring system flexibility, high vehicle comfort, safety features such as connection to a control centre, and the constant presence of vehicles in urban areas.
- By integrating it into the HVV, introduce a differentiated, competitive pricing system with a convenience surcharge, primarily based on the availability of parallel offers.
- Combine autonomous and human-operated on-demand shuttles with other modes of transport in the sustainable transport network through multimodal route planning.
- Extensive availability of on-demand services throughout the entire city and surrounding areas can be achieved by consolidating various providers into a unified outward offering.
- Establish clear rules and regulations for the safe operation of autonomous shuttles.
- Test autonomous goods transport using on-demand shuttles in order to relieve the main traffic peaks through 24/7 transport and at off-peak times (such as at night).

Description of the development path for autonomous on-demand shuttles

The development pathway for autonomous on-demand shuttles involves transforming traditional human-operated on-demand services into self-driving vehicle fleets operating in autonomous ride-pooling mode, fully integrated into the urban transport system.

The use of ride pooling providers such as CleverShuttle in 2016 marked the start of the first on-demand services in Hamburg. In 2018, the ioki shuttles operated by VHH connected the first and last mile to public transport, improving accessibility in poorly served areas of the Lurup and Osdorf districts. The concept was so successful that the VHH service was expanded to Ahrensburg in the Stormarn district, as well as Hamburg-Billbrook and Hamburg-Harburg. Since January 2023, VHH's ride-pooling service has been offered under the name hvv hop, with an expansion into new service areas. The ioki software continues to be used and the service operates exclusively between doorsteps and public transport stops (last mile). In 2019, the Volkswagen subsidiary MOIA launched its ride pooling service with up to 500 vehicles. Compared to hvv hop, MOIA offers point-to-point connections (direct route). MOIA has since significantly expanded its urban service area towards the city boundaries to 266 km² and

continued as a self-sustaining on-demand service integrated into the public local transport network. Part of the fleet has been designed to provide barrier-free transport for people with reduced mobility. In total, over seven million people have already used the service.
From 2019 to 2021, the taxi broker FreeNow offered passengers a digital service for sharing taxi journeys (myTaxi-match). As part of the 'Zukunftstaxi' (Future Taxi) project, the Free and Hanseatic City of Hamburg is promoting the transition of the city's taxi fleet to locally emission-free drives and the provision of up to 65 locally emission-free taxis that can accommodate people in wheelchairs (E-inclusion taxis). In 2023, two taxi dispatchers submitted applications for permits to operate flexible route services in accordance with § 44 of the Passenger Transport Act (PBefG). Hamburg taxis provide around 10 million journeys per year. In the future, taxis can specifically meet the transport needs of people with disabilities, elderly and sick individuals, as well as passengers who, for various reasons, prefer transport with a driver.

The HEAT shuttle in HafenCity Hamburg was one of the first projects where automated shuttles were tested in Hamburg. For autonomous operation, the vehicle was equipped with specific technical components (such as radar and Light Detection and Ranging (LiDAR)) and connected to supportive infrastructure. It was also monitored by a control centre. The HEAT shuttle was an important step towards operating with autonomous vehicles. In retrospect, not all project goals were achieved, but the project provided the stakeholders in the Free and Hanseatic City of Hamburg with substantial knowledge and experience for the further development of autonomous shuttles. Surveys have also shown that passenger acceptance of the automated driving technology used in Hamburg is high. To successfully implement this for an autonomous public transport service, it is essential to adopt a systemic approach that takes into account all components such as the control centre, the vehicle, sensors, and HD maps.

In 2019, the automated TaBuLa shuttles from NAVYA, operating at Level 2, began passenger transport in Lauenburg an der Elbe (Hamburg metropolitan region), as a vehicle attendant was essential at that time. The operating phase was preceded by the ideas phase in 2017 and the project launch with the first vehicles in 2018. This was followed by the addition of autonomous transport robots in the TaBuLa-LOG project, which were themselves transported in the automated shuttle. The follow-up project TaBuLa-LOGplus enhances the networking and coordination of various vehicles in passenger and freight transport through the implementation of control centres and process optimisation for technically upgraded VHH buses and transport robots using artificial intelligence.

The Hamburg real-world lab (RealLabHH) was able to provide important insights into the acceptance of autonomous vehicles in Hamburg with the eMoin shuttle operated by VHH and developed by Continental in Hamburg-Bergedorf. At the ITS World Congress 2021, the eMoin shuttle, unlike the HEAT shuttle, successfully operated as an on-demand service (Level 4) rather than on a fixed route. The service was very well received by the Bergedorf population and the vehicle was well utilised.

Taking a different technological approach but with similar application scenarios, tele-driving technology operates by remotely controlling a vehicle. Hamburg is the first city in Germany to test a tele-driving service (in Hamburg-Bergedorf). The company Vay uses tele-driving technology that allows a remote operator to control a vehicle from a distance. This technology can also serve as a bridging solution for autonomous driving.

Info box

'What if:' Simulation study on the impact of up to 10,000 autonomous on-demand shuttles from MOIA GmbH

Hamburg is endeavouring to develop a supply-oriented public transport service as an attractive alternative to the use of private cars. Public transport should be accessible from anywhere in Hamburg within five minutes (Hamburg-Takt). The basis for this is the traditional, scheduled public transport service, supplemented by an on-demand service which is available nationwide. Ride-pooling is a concept where multiple passengers travelling in similar directions share a vehicle, reducing traffic and improving efficiency. The vehicles reach people within a tighter local area through virtual and physical stops. The city of Hamburg is planning to deploy a fleet of up to 10,000 autonomous ride pooling vehicles throughout the city.

MOIA

	This is today Scenario 1	Launching automation Scenario 2	Scaling automation Scenario 3	Mobility turnaround Scenario 4	Mobility revolution Scenario 5
Service area size	270 km²		350 km²	700 km²	
# of Autonomous Ridepooling Vehicles	250 vehicles		2,500 vehicles	5,000 vehicles	10,000 vehicles
Price per person per km	1.20 €		0.50 €	0.45 €	0.40 €
Political push measures	None			Medium	Extensive

Figure 17: The road to 10,000 autonomous ride pooling vehicles (source: MOIA)

MOIA, in collaboration with the Karlsruhe Institute of Technology (KIT), commissioned a simulation study to examine the scalability of their ride-pooling service across various scenarios with different assumptions. The assumptions made were freely chosen by the researchers and in some cases represent extreme 'pull and push' factors. All scenarios share the common outcome that a shift in the modal split towards environmentally friendly transport modes is a result of the ride-pooling services.

The simulation study by KIT and MOIA Mobility Consulting (2024, https://solutions.moia.io/de-DE/mobility-consulting) includes several scenarios to investigate the characteristics and effects of the MOIA ride pooling service under the given and future framework conditions. Firstly, the current MOIA ride pooling service is simulated (scenario 1). The MOIA service area covers large parts of the city north and south of the Elbe (270 km²) and reaches a good 70 per cent of Hamburg's population. The other scenarios in the MOIA study show possible paths into the future with automated ride pooling vehicles:
Considering the efficiency effect through fleet automation, eliminating operational empty miles due to the absence of trips for breaks, shift starts, and ends, positive impacts on traffic have already been observed (Scenario 2). If autonomous technology is scaled up and offered at a more favourable fare, significant increases in demand can be expected (scenario 3). In these scenarios of the MOIA study, it is particularly relevant that the new offer also includes supplementary push measures as part of an overall concept (scenarios 4 and 5). According to

the MOIA study, the demand for 10,000 autonomous ride pooling vehicles can be expected in scenario 5.

Key assumptions of this model calculation include reduced prices for the ride-pooling system and increased travel times and costs for using private cars, for instance, due to 30 km/h zones and car park management. In this simulated scenario with 10,000 autonomous vehicles, ride pooling is available throughout the entire city of Hamburg. A high quality of service can be achieved with a large fleet. This results in a significantly higher occupancy rate of an average of 2.2 passengers, which, combined with the shifts in modal split, leads to approximately 25% fewer kilometres driven in the transport system. The modal split of public transport and ride pooling increases to well over 30% in this scenario.

When passengers share rides and the number of vehicles on the road decreases, it results in less congestion, reduced traffic noise, and lower CO_2 emissions. The ride pooling system means that people who do not own a car can also access the service, thereby reducing the demand for private vehicles. This relieves the overall burden on traffic and results in a more efficient transport system.
The simulation results clearly demonstrate that the technological development of autonomous driving must be implemented in tandem with transport policy measures to achieve positive effects in terms of the mobility transition.

In the context of the 2030 vision, the aim is to transform the existing ride-pooling services under the Hamburg Takt (plan to provide public transport within five minutes for all residents) into a large-scale, fully automated, and driverless system. The test phase of autonomous on-demand shuttles planned for 2024 will be based on a test fleet consisting of the funding projects ahoi (VHH, PSI, Fraunhofer Institute for Transportation and Infrastructure Systems, Hamburg University of Technology, Institute for Climate Protection, Energy and Mobility e.V. (IKEM), Ministry for Transport and Mobility Transition) with up to 20 autonomous shuttles, and ALIKE with a further 20 autonomous shuttles (HOCHBAHN, HOLON, MOIA, MOIA Operations, Volkswagen ADMT, Karlsruhe Institute of Technology (KIT), Ministry for Transport and Mobility Transition). It is acknowledged that there will still be future use scenarios requiring a driver, such as for passengers with mobility impairments, goods transportation, and certain urban areas with specific requirements.

The Hamburg Port Authority's (HPA) plans for further projects involving autonomous shuttle services show that the city of Hamburg is endeavouring to drive forward innovative and environmentally friendly solutions in the field of local public transport. Such a project could, for example, link the Steinwerder cruise terminal in the Port of Hamburg with the main railway station or the Elbbrücken S-Bahn/U-Bahn, thus offering an automated and emission-free transport option for cruise passengers. Hamburg's ambitions in the field of autonomous and connected mobility are further highlighted by the establishment of an Innovation Centre for Autonomous and Connected Driving (IAF) by the supporting federal states of the Hamburg Metropolitan Region (MRH) and Hamburg itself. The aim of this Innovation Centre for Autonomous and Connected Driving (IAF) is to monitor and assess developments in traffic and technology related to autonomous vehicles and to develop recommendations. These recommendations are specifically directed at the federal states supporting the Hamburg Metropolitan Region (MRH), municipalities, transport companies, vehicle manufacturers, and mobility service providers.

According to the plans of ride-pooling providers like MOIA, the first autonomous vehicles are expected to start operating in a ride-pooling test service in Hamburg as early as 2025, transporting people from A to B. Subsequently, autonomous vehicle fleets are to be scaled, with up to 10,000 autonomous on-demand shuttles (SAE Level 4, with technical supervision) set to form Germany's largest driverless ride-pooling fleet by 2030. The aim is to primarily serve less urban areas, complement the underground and bus services in line with the

Hamburg Tact initiative, or – where necessary – create more flexible mobility options (such as night services). An example of this is the Vier- und Marschlande area, characterised by a high density and dependency on cars and an insufficient public transport service. Since 2022, the city has been given the responsibility under the Federal Ordinance for the Approval and Operation of Motor Vehicles with Autonomous Driving Functions in Designated Operational Areas (Autonomous Vehicles Approval and Operation Ordinance – AFGBV). This includes approving designated operational areas for autonomous shuttles (§ 7 (2) AFGBV) and monitoring the fulfilment of approval requirements and compliance with the obligations associated with the approval (§ 9 (6) AFGBV).

Experts believe that digital approval processes between authorities and applicants will need to be established to allow autonomous shuttles in designated operational areas, at the latest when scaling up shuttle fleets. Furthermore, § 9 AFGBV provides the option to check at any time whether the owner is fulfilling the approval requirements and complying with the obligations associated with the approval, or to have this checked by the authorities mentioned in paragraph 3. Overall, converting the fleet to fully automated, driverless operation is a key lever to further enhance efficiency, comfort, and safety.

Fictitious User Journey 2030 - Autonomous on-demand shuttles

- Paul Kleinfeld's mobility behaviour has changed significantly over the last ten years. Since the widespread introduction of on-demand autonomous shuttles for his daily commuting needs, Paul can quickly reach the entire city without having to rely on his car. Since his first journey in the on-demand ride pooling system, he has been using the service in combination with the bus, underground, and S-Bahn. It is convenient to be able to order the vehicle to the stop closest to your home and the nearest S-Bahn [urban rapid transit system] station using your smartphone or to be able to travel directly to your destination. Paul shares his journey with other passengers travelling in the same direction, thus saving on travel costs. The journey is flexible, the seats are comfortable and it is never crowded. If Paul is not travelling by bus or train, he is happy to pay the convenience supplement compared to the standard hvv fare.

  At the official launch of autonomous on-demand shuttles, Paul was initially concerned that these new vehicles could lead to chaotic conditions on the roads. After requesting his first shuttle via the app, he is impressed by the modern, spacious interior as well as the speed and agility of the shuttle. The vehicle is also quiet and emission-free. He can book the shuttle almost anytime and anywhere and no longer has to pay attention to the timetable. He can now easily reach Grandma Kleinfeld in Vier- und Marschlande, a journey he used to make by car due to the infrequent bus services. The newly expanded shuttle services provide him with a level of freedom in public transport that he had never experienced before.

3.2.5 Digital underground and urban rapid transit system development path

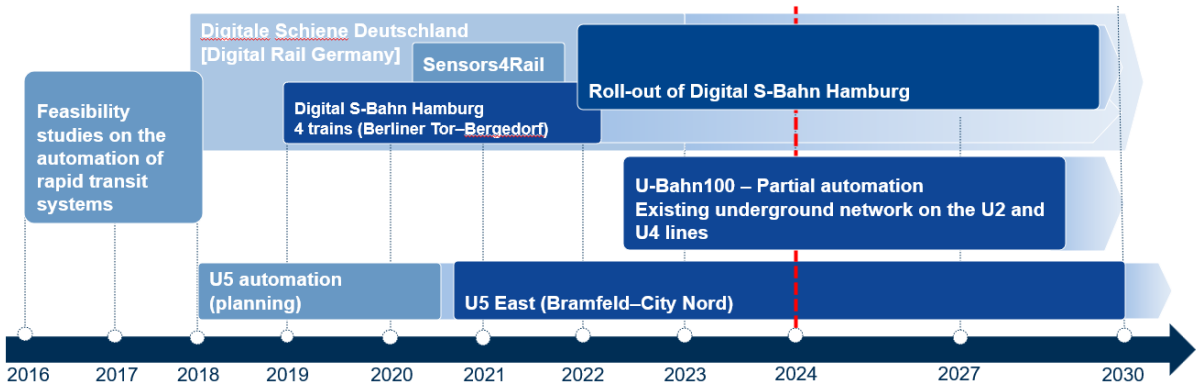

Figure 18: Digital underground and rapid transit system development path | From the feasibility study to partially and fully automated rail transport

Key focus areas 2030

S-Bahn:

- Implement infrastructure measure(s) within the national strategy '#Digital Rail Germany' (DSD).
- Develop/set up system management from 2023 to 2026.
- Equip the existing vehicles from 2024 to 2028.
- Construct the digital signal box (DSTW) Hamburg City from 2024 to 2028.
- Equip the outer branches from 2026 to 2030 and beyond.
- Develop/realise capacity and traffic management system from 2023 to 2028+.
- Further develop energy-optimised driving together with the industry.

Underground:

- Put the first section of the fully automated U5 underground line between Bramfeld and City Nord into trial operation – in sections – from 2027.
- Complete the partial automation of the underground on lines U2 and U4 by the end of 2026 for the sections between Elbbrücken and Jungfernstieg and between Christuskirche and Horner Geest with the section between Horner Rennbahn and Mümmelmannsberg to be completed by the end of 2029.
- Run the underground trains on the (partially) automated sections every 100 seconds.

Description of the digital underground and suburban railway development path

The development path for digital underground and S-Bahn in Hamburg includes projects for the extensive automation of the S-Bahn (on its 'own' direct current network), the partial automation of the U2 and U4 underground lines, and the full automation of the U5 underground line. By 2030, the Hamburg-Takt initiative aims to achieve a higher frequency of services and, in particular, an improvement in punctuality and reliability. The capacity, accessibility, and resilience of rail-based public transport will be significantly expanded.

The path began with feasibility studies investigating the introduction of digital technologies in rail transport. The aim was to make rail transport (partially) automated, efficient, and convenient. Feasibility studies have already shown that digitalisation can reduce delays (including knock-on delays, operations after delays) by around 40 percent and improve punctuality by an average of five percent.

With the Digital S-Bahn Hamburg (DSH 1.0) and the introduction of four S-Bahn trains in regular operation on lines S2 and S21 in 2022, the Free and Hanseatic City of Hamburg, in collaboration with Deutsche Bahn AG and Siemens Mobility, has launched a world first in

Hamburg as the initial project of Digital Rail Germany. Further scaling is planned to encompass the future fleet of 258 trains for the Hamburg S-Bahn. Starting in 2025, 64 S-Bahn trains equipped with technologies for automated driving will be added to the fleet. Furthermore, the next step will involve automating the city area with a digital signal box system, incorporating technologies such as the European Train Control System (ETCS) and Automatic Train Operation (ATO). This will generate additional capacity in the core area of the S-Bahn system and thus greater reliability. A research and development project for energy optimisation in digital rail operations, known as DSH 2.0, is also getting underway. The fitting out of 21 trains will be prioritised to investigate this exciting and sustainable issue on the existing ITS route (DSH 1.0).
As part of the Sensors4Rail demonstration project by Deutsche Bahn (DB) Netz AG for the ITS World Congress 2021 in Hamburg, and in collaboration with other industry partners, a vehicle was retrofitted with the latest camera, radar, and lidar technology, (satellite) positioning technology, and a digital HD map. This was part of the Digital Rail Germany initiative. The train was enabled to perceive its surroundings and locate itself precisely and continuously in real time. The sister project of the Digital S-Bahn Hamburg was able to demonstrate that, even on routes that are not fully digitalised, this supplementary technology allows trains to run closer together, thereby increasing the capacity of a route.
Partial automation of the underground is being implemented on sections of the existing U2 line and the entire U4 line, while full automation is planned for the new U5 line. The first section between Bramfeld and City Nord is already under construction. Trial operations on the section between City Nord and Sengelmannstrasse are scheduled to begin in 2027. The automated underground offers greater punctuality and frequency, along with enhanced flexibility and efficiency. The growing population and the city's expansion will necessitate additional capacity in the underground network, which cannot be significantly increased within the existing system. Automatic operation will gradually make it possible for trains to run at 100-second intervals from 2029. Trains can be deployed according to demand; for instance, they can be extended during peak times or major events, or shortened and used flexibly during off-peak periods. For the U5, train control and security will be managed centrally from the underground control centre, where train speeds and distances between trains will be continuously monitored. The automatic control system manages driving, stopping, and the opening and closing of train doors. The platforms will be equipped with platform screen doors to ensure that trains can only depart when both platform and train doors are properly closed.

Fictitious user journey 2030 – digital underground and suburban railway

- Linh Nguyen's commute has been much more comfortable since the introduction of automated underground and suburban trains and the new transport service offers a real alternative to owning a car. The partial automation of the underground lines U2/U4 and the full automation of the U5 and S-Bahn services provide greater punctuality, frequency, and flexibility. In addition, the trains are no longer as crowded as they used to be thanks to the increased frequency. Linh can therefore walk to the next stop in the morning without having to look at the clock or remember the timetable. She can get on the next train there, and doesn't have to wait long to change trains either, since the trains now run at 100-second intervals. This makes both the outbound and return journeys much more relaxed and flexible for Linh, significantly shortening her travel times. This means that Linh can rely on public transport and no longer needs to worry about finding parking spaces or dealing with traffic jams.

- Karl Schneider works as a dispatcher at S-Bahn Hamburg. The automation of the S-Bahn means that the capacity of Hamburg's S-Bahn trains will be increased, since more people can be transported in less time. With the Hamburg-Takt service initiative, Karl increases flexibility for passengers, allowing them to spend less time at stations or stops and plan their journeys more effectively. Now that more people are travelling by train, there is also

less traffic on the roads. The punctuality of trains and the reliability of the S-Bahn network have also been significantly improved.

3.2.6 Cooperative systems development path

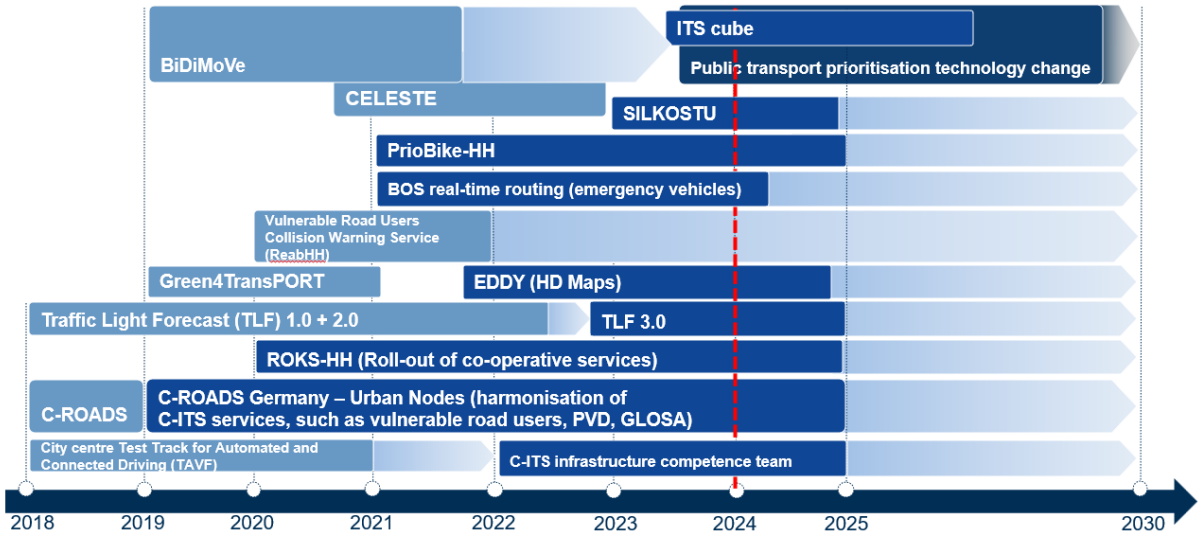

Figure 19: Cooperative systems development path | From C-ITS test fields to the rollout and operation of C-ITS services

Key focus areas 2030

- Smart prioritisation of public transport (approximately 600 traffic lights and up to 1,800 buses).
- Prioritise emergency vehicles.
- Increase road safety for vulnerable road users through networking and additional services such as infrastructure-to-vehicle communication (I2V).
- Promote active mobility through more pedestrian and cycle-friendly management of traffic lights.
- Support automated driving from an infrastructure perspective by improving the vehicle's self-positioning capabilities and ensuring the functional safety of Signal Phase and Timing Information (SPTI) provision.
- Provide traffic and warning messages about construction sites or danger spots.
- CAM messages as a new communication standard between vehicles and the infrastructure as well as in traffic guidance and control.
- Test the enforcement of traffic regulations via this communication channel and apply it within the legal framework. Offer support in the further development of the legal framework for this topic at the federal level.

Description of the cooperative systems development path

Co-operative transport systems are understood to be the interaction of different networked transport systems. Communication between vehicles (V2V) and with the transport infrastructure (V2I) results in an exchange of information between the various parties involved. Hamburg relies on the implementation of C-ITS services for co-operative systems. The cooperative systems development path includes the beginnings of the C-ITS test fields and describes the development towards the comprehensive rollout and operation of C-ITS services throughout the city. Hamburg aims to test, pilot, and roll out the first C-ITS services where appropriate. The development path comprises a total of four phases:

1. **Test phase:** In this phase, various C-ITS services are being tested to check their feasibility in Hamburg. The Test Track For Automated And Connected Driving in the Hamburg city centre, for example, is used for this purpose. In 2018, the installation of ITS-G5-based communication systems began here. This C-ITS test field with V2X communication technology offers realistic and challenging traffic situations. At the Test

Track for Automated and Connected Driving, Hamburg is working closely with research and industry on use cases in order to harmonise the use cases for connected driving and drive forward the standardisation of C-ITS messages and components (such as Public Key Infrastructure or PKI). Various C-ITS projects have been implemented and trialled on the Test Track for Automated and Connected Driving in the past. The C-ITS Infrastructure Expertise Team (CIIK) is responsible for the continuation and expansion of the test track. The 'Vulnerable Road User Collision Warning Service' project in the Hamburg real-world lab aimed to enhance the attractiveness and safety of pedestrian, bicycle, and scooter traffic (vulnerable road users) by connecting selected elements of the traffic infrastructure with road users. This facilitated the optimisation of mobility and provided collision warning services to enhance the safety of vulnerable road users.

2. **Pilot phase:** Following the successful test phase, selected C-ITS services were deployed in a pilot phase on a limited number of roads and junctions. This makes it possible to test the C-ITS applications in a real environment and gain further insights into their benefits and challenges. In the TLF 2.0 project, the process data from around 800 traffic light systems was made available on the urban data platform without discrimination. This data can be used to implement various services, such as a traffic light forecasting service. For example, the PrioBike-HH project uses this data to implement a traffic light phase assistant for cyclists in the PrioBike app. At the same time, a speed recommendation for cyclists was erected in the form of a signpost on the cycle path near Dammtor station to reduce unnecessary waiting times.
   The 'Authorities and Organisations with Security Tasks (BOS) Realtime Routing' project aims to reduce the travel time of special operations vehicles. Possible methods to achieve this goal include optimising routing by integrating traffic and traffic light data, influencing traffic lights based on deployment needs through V2I communication, and informing other road users about emergency journeys through vehicle-to-vehicle communication. Traffic light prioritisation of emergency vehicles along Ludwig-Erhard-Strasse is being tested in the pilot phase. Dynamic and demand-based traffic light prioritisation of public transport was successfully tested on the M26 bus route in the BiDiMoVe project using networking via the ITS-G5 radio standard. The Green4Transport project aimed to use V2X technology to identify and prioritise heavy goods vehicles at selected traffic light intersections in the port, enhancing traffic flow and safety while reducing emissions. As part of the EDDY project, high-resolution map data is collected from specific areas or regions and then published in a format accessible to the public, in accordance with transparency and open data guidelines.
   In the CELESTE research project, which enables dynamic speed limits in urban areas, the system adapts the speed limits to the respective conditions and reacts to unforeseen events in order to increase road safety. The SILKOSTU project raises awareness of secure C-ITS communication among relevant public sector institutions. As part of the project, a Roadside Unit (RSU) and On-Board Unit (OBU) are being developed which are capable of operating various communication channels in order to investigate extremely stringent safety requirements, including in the area of bus and emergency vehicle prioritisation. The ITS-Cube serves as a preliminary project for the technological transition of public transport prioritisation from analogue to digital radio. This includes reducing travel time, minimising braking, optimising traffic flow, and developing an ITS concept for bus prioritisation with a rollout schedule up to 2030.
3. **Rollout:** At the end of the pilot phase, C-ITS services were rolled out to other roads in Hamburg. This required the installation of infrastructure elements based on the ITS-G5 standard, enabling the provision of C-ITS services to a larger number of vehicles and road users. As part of projects such as the Rollout of Cooperative Systems in the Hanseatic City of Hamburg (ROKS-HH) and C-ROADS Germany – Urban Nodes (CRG-UN), C-ITS services such as the Green Light Optimal Speed Advisory (GLOSA)

and Time-to-Green (TTG) have been progressively implemented at over 100 traffic signal nodes. Equipping uninterrupted routes with these services can lead to a stabilisation and optimisation of traffic flow and at the same time to a reduction in pollutants. The Traffic Light Forecast (TLF) 3.0 project builds on its predecessors TLF 1.0 and 2.0, aiming to automate the processes involved in creating traffic data maps (MAPs) to accelerate the project rollout and increase output per unit of time.

4. **Operation:** Once the cooperative systems have been rolled out in Hamburg, they will be put into regular operation and further optimised. This includes, for example, near-real-time monitoring and maintenance of the infrastructure as well as adapting C-ITS services to changing traffic conditions. A monitoring centre for the installed Roadside Units has already been successfully implemented for this purpose. This allows the operating status of the roadside units to be monitored or updates to be imported. Other operational systems (such as MAP management) and processes are also being developed and implemented.

The use of C-ITS technologies and services enables more efficient traffic management, leading to reduced pollutant emissions and improved road safety. Dangerous situations can be avoided by exchanging information between traffic infrastructure and networked vehicles. The prioritisation of public transport and emergency vehicles is optimised through the integration of C-ITS, allowing vehicles to be prioritised and directed more efficiently to improve traffic flow. Road safety for pedestrians and cyclists can be increased through I2V communication. Cycling is promoted through the networking and additional services of C-ITS, which provide real-time information on cycle paths, traffic conditions, and potential hazards. Supporting automated driving at the infrastructure level enables communication between traffic infrastructure and vehicles to ensure the seamless integration of automated vehicles.
The use of C-ITS services improves traffic monitoring, which contributes to more effective enforcement of traffic rules and regulations. The C-ITS Directive of the European Parliament promotes the introduction of technologies for communication between vehicles and infrastructure to enhance the safety, efficiency, and sustainability of transport. It also defines requirements for the introduction of C-ITS as well as framework conditions for data protection and data security in order to create uniform standards for cooperative transport systems in Europe and to facilitate the integration of C-ITS into existing transport systems.

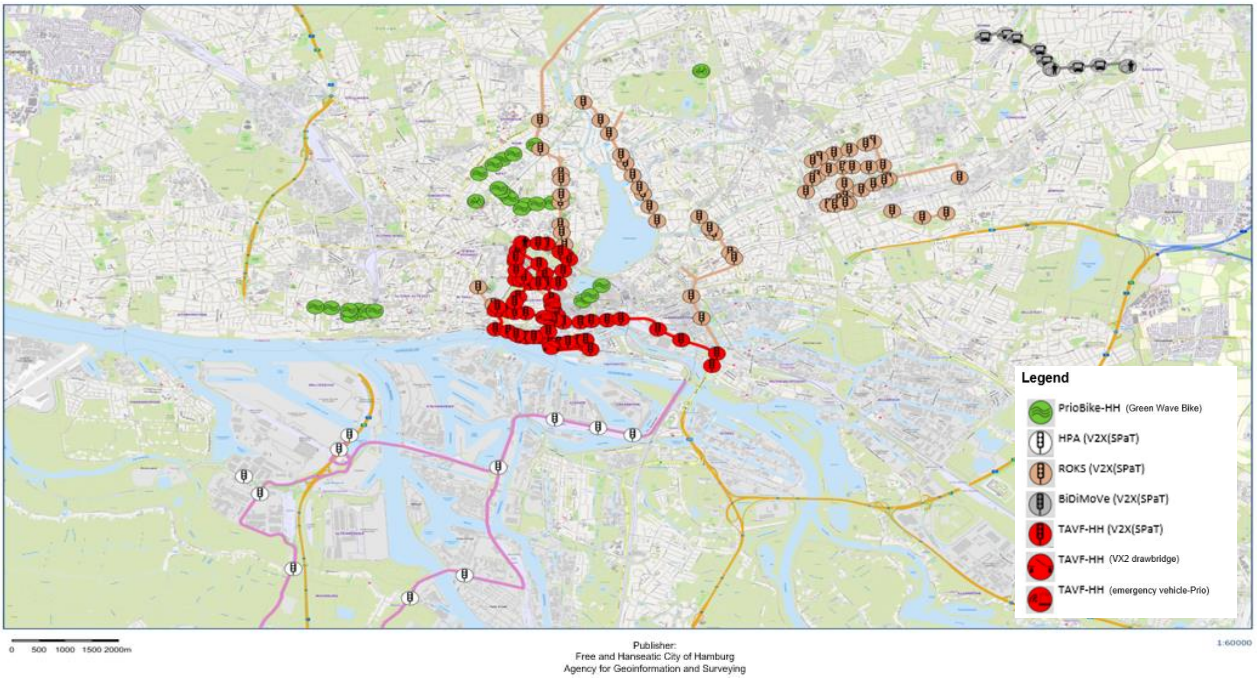

Figure 20: C-ITS services in Hamburg (source: Agency for Geoinformation and Surveying)

Fictitious User Journey 2030 – Cooperative systems

- In dry weather, Ida Anderson enjoys being outdoors and chooses to travel to her personal meetings outside her home office using a combination of public transport and a rental bike. Since Hamburg has smart traffic lights that prioritise buses and on-demand shuttles, she knows that she can get around faster than with a car-sharing vehicle. Ida can continue her journey from the bus stop on one of the many rental bikes. At some intersections, cyclists and pedestrians are given priority, and with speed recommendations via an app and advisory pillars indicating the optimal cycling speed, she can travel more safely, quickly, and smoothly.

- In rainy weather, Ida's friend Lasse Larsson uses a car-sharing pass vehicle to get to his meetings. Like many other newer vehicles, this vehicle is able to send and receive Cooperative Awareness Messages (CAM). Since many road users switch to their own cars when it rains, traffic is heavier and dangerous situations become more frequent. Lasse turns right at a poorly visible intersection, and thanks to direct communication, the vehicle automatically brakes as he did not see a rapidly approaching cyclist.

- An accident has occurred on an alternative route and his vehicle receives a message about an approaching emergency vehicle. This allows Paul to make way quickly, which is also noticed by the vehicles without this technology travelling in front of and behind him. The traffic jam clears quickly, because the traffic lights in front of him also prioritise the emergency vehicle.

- Konstantin Krämer is a part-time paramedic and is called to an accident with his team. Since emergency vehicles are prioritised at many traffic lights, vehicle journey times can be significantly reduced. In addition, routing has been improved in recent years, because traffic and traffic light data are included in the planning process. Communication between the vehicles enables other road users to react more quickly and in good time to Konstantin and his emergency vehicle and create space. Injured people can thus be helped even more quickly.

3.2.7 Digital car park management development path

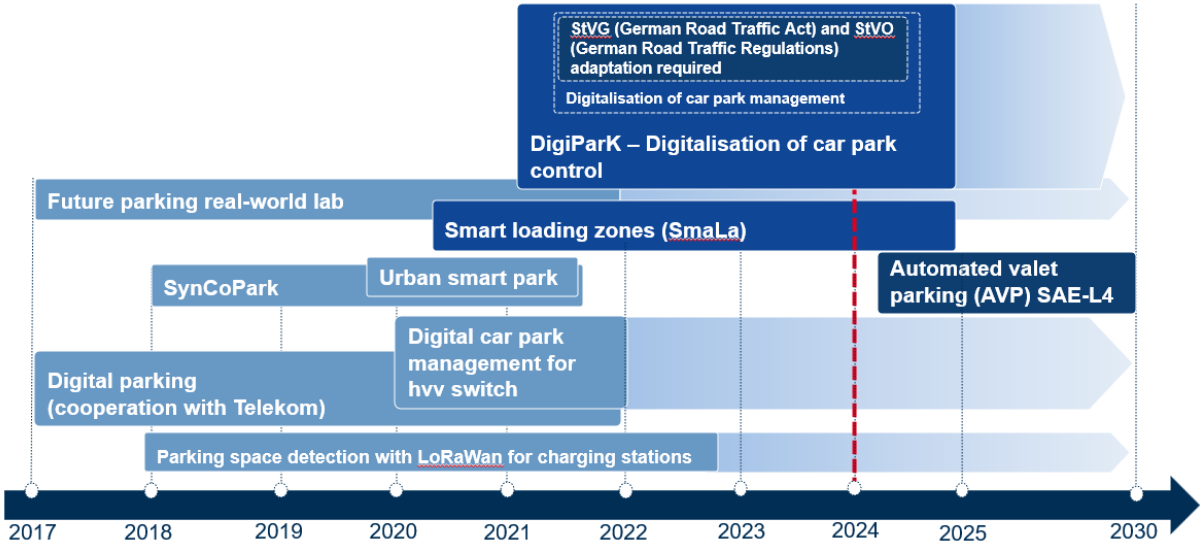

Figure 21: Car park management development path | From parking space detection to complete digital parking management

Key focus areas 2030

- Utilise sensors and data analysis for forecasting car park occupancy and providing real-time information on parking pressure.
- (Partially) automate parking space enforcement by having scanning vehicles scan the licence plates.
- Use automated valet parking (AVP) to improve traffic flow and reduce car park congestion.
- Reduce parking space search traffic with a digital parking guidance system.
- Expand smart loading zones for coordinated and efficient delivery traffic and make them legally compliant.

Description of the digital car park management development path

The digitalisation of car park management is to be driven forward by 2030 as part of the development path. In the process, car parking space detection will evolve into a fully digital car park management system. The creation of the necessary legal foundations and framework conditions is central to this development. This also means that laws need to be adapted at federal level. In recent years, numerous projects have been developed and tested in Hamburg, contributing to the increasing digitalisation of car park management.

An important component was the State Traffic Authority's launched meta-project 'Future Parking Real-World Lab', which encompassed several aspects of the digitalisation of car park management: A specialised system was developed to support personnel management for conducting car park inspections as well as the administration of over 2,000 parking meters. Essential data sets, such as public car parks, the locations of parking meters, residential parking zones, and control areas, were recorded in a geographic information system and have been regularly maintained since then. The recording of offences was switched from outdated, heavy data capture devices to smartphones with a dedicated app. Since March 2021, options for automating parking enforcement have also been investigated and developed.

The consolidation and further development, particularly the automation of stationary traffic controls, is being carried out as part of the DigiParK (digital car park management) project. The scanning of licence plates, for instance, by scanning vehicles, is intended to enable

automated or semi-automated control of the car parks. This makes it possible to organise car park management more effectively and increase road safety. To enable these developments in public spaces, both the necessary technical and (federal) legal frameworks for automation must be established. The technologisation of parking enforcement is intended to increase efficiency and reduce the need for personnel.
Additionally, Deutsche Telekom, in collaboration with the State Traffic Authority, tested data collection through the installation of around 1,000 sensors in parking spaces as part of the 'Digital Parking' project. In combination with additional data, the system provides the State Traffic Authority with forecasts of parking space utilisation and sends real-time information on parking pressure in specific areas of Hamburg. Hamburg can continue to use the data from the Telekom sensors for around 1,000 parking spaces until the end of their battery life (until approximately 2029). However, the project will not be continued due to strategic reorganisation at Telekom.
Telekom's embedded parking space sensors enable digital car park management for hvv switch, providing real-time information on the availability of parking spaces for car-sharing vehicles at mobility stations (hvv switch points). This facilitates the use of car sharing when there is high parking pressure in city centre areas.
Projects such as SynCoPark and Urban Smart Park (USP) were pilot initiatives that demonstrated automated parking at the Elbphilharmonie and the Landungsbrücken. Automated valet parking in the area of fully automated driving (SAE L4) can improve the flow of traffic in future, because it reduces the time-consuming and inefficient manoeuvring involved in searching for a parking space. Secondly, the car park load is reduced by minimising the space required for parking and exiting. This can help to reduce the need for car parking spaces. Stress and frustration from parking and searching for spaces are reduced, thereby improving the quality of life, particularly for local residents.
Urban logistics transport is faced with growing transport volumes as a result of increasing online trade. Digitally reservable delivery slots in designated loading zones can help distribute delivery traffic more evenly across the city, reduce it overall, and decrease traffic congestion caused by courier, express, and parcel services (CEP services). The first smart delivery and loading zones (SmaLa), implemented as part of the federal funding programme 'Digitalisation of Municipal Transport Systems' by the Federal Department for Digital and Transport, follow this approach. They will be tested at up to 25 locations by the mid-2020s to reduce double-parking by delivery vehicles.

Fictitious user journey 2030 – digital car park management

- Johanna Sommer is visiting Hamburg for a concert at the Elbphilharmonie and has no problem finding a parking space with her car-sharing e-car. Thanks to the ability to predict car park occupancy and the sensors at hvv switch points, she can see on her vehicle dashboard whether the electric charging station is occupied or if the parking space is blocked by an unauthorised vehicles. This means that Johanna can drive directly to free parking spaces without having to search for a long time. This makes the journey to the Elbphilharmonie much more relaxed and shortens her journey time.

- Bodo Hoffmann lives near a residents' car park. When visiting friends, Bodo takes advantage of the option to apply online for a visitor parking permit, which is charged on a daily basis. The resident parking areas are freely available on the City of Hamburg's transport portal. Bodo's friends benefit from the reduced parking pressure, because they have a better chance of finding a parking space near his home.

- Lasse Larsson works in Car Park Management at the State Traffic Authority. Smartphones now make it much easier to detect incorrectly parked cars. Moreover, scan cars make it possible to determine in advance where incorrectly parked cars are located. Lasse can then go directly to these locations and record the improperly parked vehicles using his

smartphone. His work has become more efficient, and staffing across the entire Car Park Management of the State Traffic Authority can be more targeted and needs-based. The simplified and digitised monitoring has resulted in fewer illegal parkers, a reduction in double-parked vehicles, and improved traffic flow.

- Smart loading zones make the working day easier for parcel deliverers like Ida Anderson. The ability to reserve delivery slots in the smart loading and delivery zones in advance with an app has resulted in a more even distribution of delivery traffic, which eases rush hour congestion and reduces parking pressure. The daily work routine for Ida and her team has been somewhat eased since she can now more efficiently find a loading zone and carry out the parcel distribution to the final delivery address from there. The staff scheduling has become more efficient and resource-saving.

3.2.8 City and port logistics development path

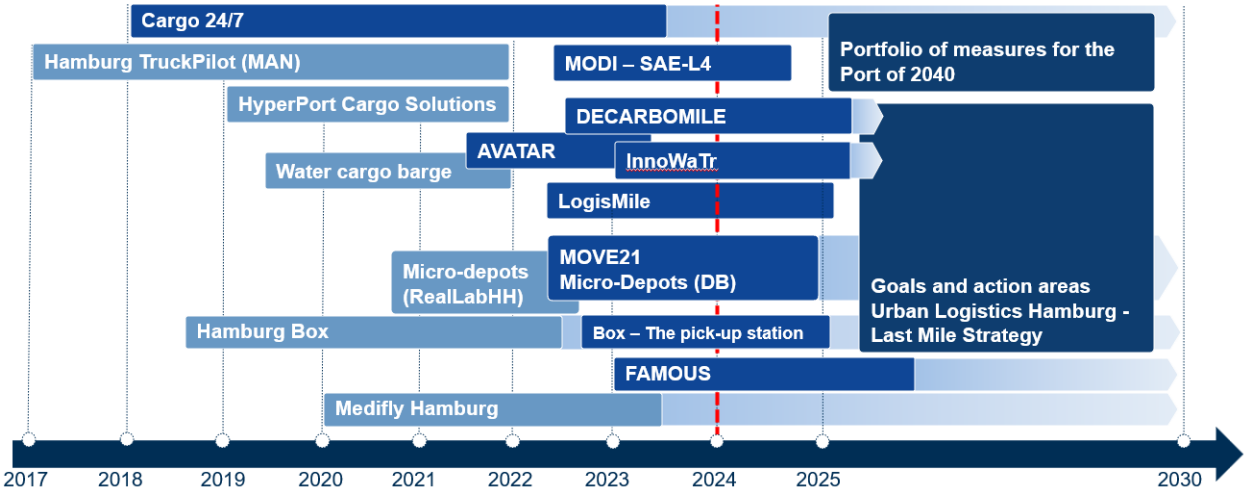

Figure 22: City and port logistics development path | From smart city logistics to autonomous goods transport

Key focus areas 2030

- Establish numerous micro-depots/hubs in urban areas and use alternative transport methods such as e-cargo bikes for efficient goods distribution.
- Cross-provider parcel lockers where multiple providers use a single station to deliver to end users at central hubs.
- Use emission-free delivery vehicles and gradually supplement them with autonomous delivery vehicles.
- Gradually introduce the prioritisation of emission-free delivery vehicles for pedestrian zones with vehicle access, as well as for the use of loading zones, in coordination with districts and police stations.
- Examine whether waterways can be used as an environmentally friendly alternative to road transport in urban goods transport.
- All commercial vehicles use the Environmental Fleet Seal.
- Promoting autonomous and sustainable systems in the port.

Description of the city and port logistics development path

The development path for city and port logistics encompasses projects focused on the evolution of smart city logistics up to autonomous goods transport. In the Hamburg metropolitan region, large quantities of goods are transported daily, which are essential for the city's supply and the economy. An efficient, smart, and environmentally friendly design of city and port logistics is therefore a key component for sustainable mobility in Hamburg. This transformation is supported by the implementation of various projects based on the 'Last Mile Strategy' 2030 and the Port Development Plan 2040 (draft). Overall, around a third of inner-city traffic is attributable to commercial transport, including city and harbour logistics.
The electrification of delivery vehicles plays an important role in creating climate-friendly transport and is already clearly visible in the city centre through the use of flexible and fast e-cargo bikes by CEP services such as Deutsche Post, Hermes, and UPS.
The FAMOUS project aims to develop an asset-sharing market module for the reservation and shared use of charging infrastructure, integrating it with network condition monitoring to better predict electricity demand. The Medifly Hamburg project has taken the initial steps to enable the transport of medical goods using drones, for example, for hospitals. The integration of a medical airfreight service ensures efficient and rapid supply. The EU project DECARBOMILE builds on the findings of a project on the use of pontoons/boats (AVATAR project) and a feasibility study on the use of Hamburg's waterways (Water Cargo Barge project) for goods delivery. The project aims to pilot parcel delivery using an electrically powered boat on the Hamburg canals of the Elbe and Alster, followed by last-mile distribution using e-cargo bikes.

The Connected River and INNOWATR 2.0 projects also explore the potential for increased use of waterways for logistical activities.
Digital services for alternative delivery concepts are becoming increasingly important and are being researched and tested in numerous projects with Hamburg's involvement. The LogisMile project demonstrates how autonomous hub vehicles can be combined with autonomous delivery devices to distribute goods. Additionally, Hamburg is implementing pick-up points to make courier, express, and parcel (CEP) services more efficient and environmentally friendly, while also better engaging end customers. The installation of parcel lockers at several U-Bahn and S-Bahn stations is being rolled out nationwide by Deutsche Bahn and DHL as part of the 'Box – The Collection Station' project. Hamburg will have up to 30 locations where customers can drop off or pick up their parcels at public transport stations.
The development of micro-hub concepts is being driven forward in the current EU project Move21, for example. Here, passenger and goods mobility are being combined and piloted at least two locations. In a neighbourhood hub in Altona, for example, a micro-depot already shares space with social and cultural uses. Starting from micro-depots, parcels are delivered further within neighbourhoods using alternative transport methods such as e-cargo bikes, in a way that reduces traffic and emissions. The experiences from these projects show that suitable private and public spaces for such initiatives are scarce, which is why semi-public spaces, such as those in car parks, are becoming increasingly important. In the future, the real estate industry will also need to play a more significant role in the implementation of micro-hubs.
Building on the successful tests in the TruckPilot project by MAN at an HHLA site in the Port of Hamburg, efforts will be made in the coming years to develop use cases and solutions with the industry for bridging the gap towards autonomous lorries. This aims to address the shortage of drivers and the simultaneous increase in goods traffic. Hamburg will serve as a test city for the MODI project and test partially to highly automated vehicles on public roads. The project will work together with around 30 European partners on the standardisation of Cooperative Connected and Automated Mobility (CCAM) in the corridor between Oslo and Rotterdam. Goods are occasionally transported by lorry from Copenhagen or Rotterdam, with MODI laying the foundation for the development of SAE Level 4 vehicles.
Additionally, the optimisation of various slot booking systems within the Cargo 24/7 project can significantly reduce waiting times for lorry drivers at the container terminals in the port.
The development path of commercial transport demonstrates how digitalisation and innovative projects can support the mobility transition, enabling more efficient and sustainable logistics. Finally, digital solutions such as smart route planning and the use of autonomous vehicles for parcel delivery can also help to reduce urban traffic.

User Journeys 2030 – city and port logistics

Amina Ndlovu is a retailer in Hamburg and has placed orders for goods. Now she is waiting for their arrival. Instead of having to wait several days to receive deliveries from delivery vehicles as in the past, additional options are now available. The delivery is made to Amina by an autonomous delivery van with a delivery robot that has received the goods from a micro-depot. Her customers now also have various options for receiving their purchases: Instead of having to drive to the shop themselves, Amina uses an app to order a delivery by cargo bike, which delivers the goods directly to the customer with zero local emissions.

3.2.9 Maintenance management development path

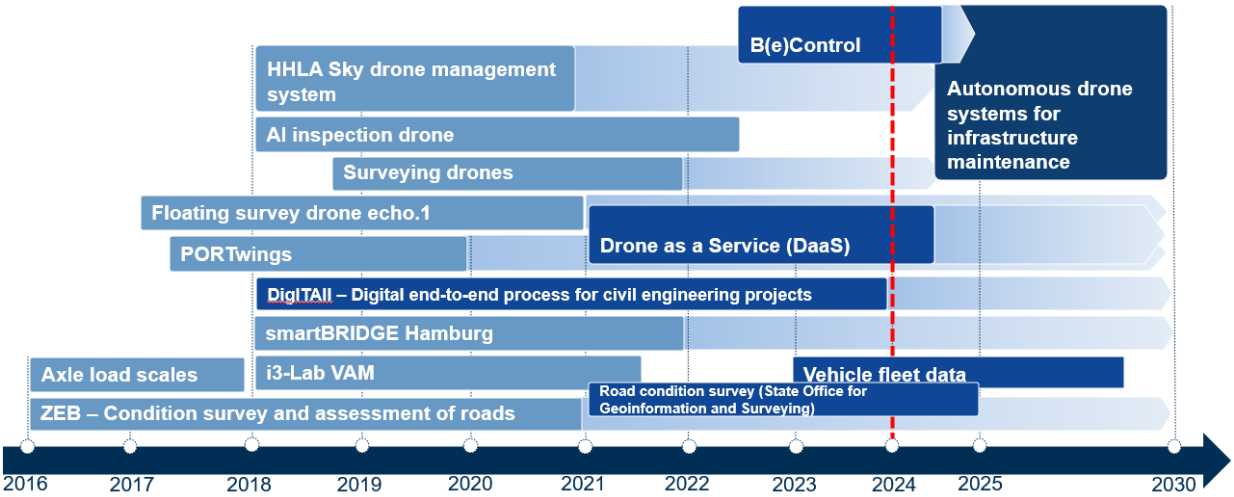

Figure 23: Maintenance management development path | From digital condition recording to automated maintenance management

Key focus areas 2030

- Utilise autonomous drone systems to enhance the efficiency of infrastructure maintenance in the Port of Hamburg and the urban area, making infrastructure management smarter, extending the services of disaster response units, performing security tasks, monitoring environmental conditions, and contributing to cost savings.
- Utilise aerial data to facilitate the maintenance, planning, and development of bridges, buildings, dykes, and roads.
- Utilise sensor measurements and additional data to automate maintenance management, enabling predictions of when maintenance and repair work on infrastructure components will be necessary.
- Detect the road condition and introduce a standardised process to provide a current assessment of the road condition.
- Utilise vehicle fleet data to support the operational maintenance of roads.
- Improve the coordination of the construction authorities/contractors.
- Examine the extension of the existing axle load scale system to prolong the lifespan of bridge infrastructure, aiming to obtain a second certified and legally recognised enforcement instrument for object detection and owner identification (‘Weigh in Motion’).

Description of the maintenance management development path

Maintenance management is evolving along its development path from simple digital recording of infrastructure conditions to automated maintenance management. Through the use of modern technologies and geographic information systems, all data for the assessment and evaluation of road conditions are currently recorded, managed, and georeferenced electronically. This facilitates precise localisation and visualisation of road condition data on digital maps. The digitalisation of maintenance management not only facilitates the efficient administration of road infrastructure but also enables informed decision-making regarding the prioritisation of maintenance measures.

Scan vehicles, scan cargo bikes, sensor measurements on transport infrastructure structures, digital twins, or drones will accelerate automation processes in maintenance management in the future. They will increase the reliability and availability of facilities and vehicles, reduce costs, and improve safety and efficiency in operations. Infrastructure maintenance is a key component of maintenance management. By predicting potential failures or issues, maintenance work can be planned and optimised to minimise downtime and extend the lifespan of the infrastructure.

The assessment and evaluation of road conditions in Hamburg have been regularly conducted since 2003 according to the unified 'Condition Assessment and Evaluation' (ZEB) standard. It is a crucial foundation for road maintenance management. The Condition Assessment and Evaluation (ZEB) method makes it possible to objectively and systematically record and assess the condition of roads. Various parameters such as surface condition, cracks, and unevenness are recorded and evaluated. The assessment is based on defined criteria and takes the form of status grades. Based on the Condition Assessment and Evaluation (ZEB), and considering other factors such as traffic importance, measures for the maintenance and improvement of roads are prioritised. Vehicle fleet data is used as a further data source to identify safety hotspots in the Hamburg road network.
To better estimate the constant loads on the Süderelbbrücke, an axle load scale was installed in 2016. This scale allows for the weighing of lorry transports in flowing traffic at speeds of up to 100 km/h. This facility made it possible to collect data that serve as reference values for the standard calculation models. By using this real data, it was possible to make more accurate and precise calculations of the axle loads of lorries. In the port, the smartBRIDGE pilot project improved the maintenance of the Köhlbrand Bridge in the Port of Hamburg. In this process, the data streams from existing and new monitoring systems, as well as the results of regular structural inspections according to DIN 1076 specifications, are consolidated into a digital twin of the bridge. The large volume of diverse data is structured and sensibly categorised to make it quickly usable. The methodical approach and technological implementation of digital twins for predictive maintenance management were generalised by BIM.Hamburg on behalf of the Federal Department of Transport and Digital Infrastructure for bridge construction in the federal motorway network as part of the Digital Twin Master Plan.

Since 2018, various drone applications have been tested and introduced to make inspections and monitoring operations in the port and urban area faster and more efficient. The survey floating drone 'echo.1' is the first autonomous surface vehicle in the Port of Hamburg. With compact high-performance sensors, the drone can further enhance data on water depths by surveying very shallow areas up to the depth navigable by inland vessels, which are difficult to access with a survey boat.
The PORTwings drone control centre was developed by the HPA to enhance safety in the harbour area through the use of teleoperated drones beyond the visual line of sight and mobile sensor systems. The goal was to introduce a large-scale situational awareness service to support the inspection, maintenance, and expansion of the port infrastructure.
An AI-supported inspection drone that efficiently analyses inspection data and draws automatic conclusions was further developed by Helmut Schmidt University Hamburg and deployed in Lufthansa Technik hangars. By focusing on the inspection of aircraft, particularly regarding lightning damage, the system can enhance aircraft maintenance.
Survey drones are increasingly being used by infrastructure operators such as HOCHBAHN, since they provide an efficient, cost-effective, and accurate solution for a variety of surveying tasks. The detailed aerial imagery allows for precise monitoring of the rail network, construction sites, and depots, contributing to the safety and reliability of rail transport. They also provide high-quality data that is extremely useful for planning, construction, and maintenance in various areas.
The HHLA Sky drone management system can centrally control missions of both its own and external drones, which are beyond visual line of sight and simultaneously located in different countries. In collaboration with the B(e)Control project and the establishment of a central drone control centre, the State Office for Roads, Bridges and Waterways is working with HHLA Sky. The goal of the collaboration is to use aerial data to facilitate the maintenance, planning, and development of bridges, buildings, dykes, and roads.
The control centre functions and sensor concepts of the drones, which are being developed and deployed in real operations at the port as part of the HPA's 'Drone as a Service' (DaaS) project, are based on the innovation partnership between HHLA Sky and HPA, established at the end of 2021. These automated drone systems will enhance the efficiency of infrastructure

maintenance in the Port of Hamburg, make infrastructure management smarter, expand the services of disaster protection units, perform security tasks, monitor environmental conditions, and contribute to cost savings. Digital technologies and data analysis help to improve the efficiency and accuracy of maintenance measures in the transport infrastructure sector.

Fictitious user journey 2030 – maintenance management

- Johanna Sommer works at the Port of Hamburg and is responsible for monitoring the Köhlbrand Bridge. In addition to the conventional structural inspection, which takes place every three to six years, a digital twin of the bridge supports maintenance management. Maintenance of the bridge is made much easier because problems are recognised immediately. The drones and sensors used detect damage and irregularities on the bridge. As soon as a problem is recognised, targeted repair measures can be initiated. Johanna can call up information about the condition of the bridge directly from the control centre and plan appropriate repair or maintenance work. The service life of the bridge is extended by many years and the harbour remains functional.

- In addition to the bridge, roads throughout the entire city are digitally recorded and assessed for their condition. For specific purposes, automated drone systems and sensor technologies are also used to monitor the infrastructure. Bodo Hoffmann works for the City of Hamburg and, like Johanna Sommer, benefits from digitalised and automated maintenance management. This allows problems with the infrastructure, such as defective streetlights, potholes or other damage to roads, tunnels, bridges or locks, to be recognised at an early stage. Scan cars, data from vehicle fleets, special cargo bikes, and sensors on the infrastructure record damage. Drones are used on bridges or over construction sites. Infrastructure maintenance is now much easier, because it can now be controlled primarily from the control centre. This means that damage and problems can be recognised and rectified more quickly. Hamburg residents like Linh Nguyen also benefit from this. The roads have become safer and there are fewer roadworks due to dilapidated infrastructure, traffic jams, or accidents.

4 Digital mobility organisational structures

The organisational structure builds on the successful inter-agency structure prior to the ITS World Congress. Important developments and decisions are discussed and made by the Digital Mobility Steering Committee. Key topics are addressed in inter-agency specialist discussions and in so-called ‘deep dives’. On the Senate side, the Ministry for Transport and Mobility Transition is responsible for implementing the Digital Mobility Strategy.
The Digital Mobility Community is made up of small and medium-sized enterprises, start-ups, corporations, and interested residents of Hamburg who are involved in digital mobility issues. This community is actively involved in the strategic process and is informed and engaged through public events such as dialogue forums. An open dialogue is encouraged to incorporate ideas, opinions, and expertise from various sectors.
The Hamburg Commissioner for Data Protection and Freedom of Information has the opportunity to participate in dialogues and provide insights on general data protection requirements.

UITP Summit 2025/2027

Following the decision that Hamburg will host the UITP Global Public Transport Summit in 2025 and 2027, the organisational framework will be established within the New Mobility Solutions Hamburg GmbH (NMS). The UITP Congress is regarded as the world’s most important mobility congress and includes a trade fair. In a selection process, Hamburg prevailed over Vienna, Geneva, and Istanbul. Hosting the UITP Congress strengthens Hamburg’s role as the centre of the mobility world. The application was part of the declaration of intent for the ‘Metropolitan Model Region for Mobility’, which was presented by the federal government and the City of Hamburg. The bidding consortium consisted of Hamburger Hochbahn AG, Hamburg Messe und Congress GmbH, and MOIA GmbH, supported by the Free and Hanseatic City of Hamburg and the Hamburg Convention Bureau.

Financing structures and funding programmes

Hamburg has been very successful in initiating and implementing projects, collaborations and acquiring funding since 2016. The projects are important development and deployment projects to further advance the digitalisation and automation of mobility in Hamburg. The majority of the projects were and are (proportionately) financed by federal and EU subsidies. So far, the cooperation partners and Hamburg have been able to raise a three-digit million amount in funding. The implementation of the projects relies not only on the expertise provided but also on the financial contributions from cooperation partners in business and industry, such as Deutsche Bahn AG, Volkswagen AG, MOIA GmbH, BMW AG, Siemens Mobility GmbH, NXP Semiconductors, IAV GmbH, and others.

The Ministry for Transport and Mobility Transition secures the necessary own funds for selected Hamburg projects, such as the shuttle project ‘Ahoi’, and manages the coordination with the funding provider. Since digitalisation is an overarching issue that affects all authorities, state offices, and municipal companies, projects are generally planned and executed under their own budgetary responsibility.

The participating specialist authorities, state offices, and municipal companies are continually professionalising the structures for applying for funding, project implementation, and project accounting. As of December 2023, the following projects in the context of ‘Digital Mobility’ have been or are being funded by federal or EU funds, or have had their funding concluded:

No.	Funding guideline	Federal government or EU	Project name	Funding share	Federal/EU funds	Own funds	PM Total	Duration
				%	Thousand €	Thousand €	Thousand €	to
1	DKV	Federal	TAVF-HH	50	2,513	2,687	5,200	31/12/2020
2	ACD	Federal	BiDiMoVE	100	1,858	2,501	4,359	31/12/2020
3	DKV	Federal	V2X-HH	50	4,319	4,319	8,638	31/12/2021
4	DKV	Federal	TLF 2.0	50	806	1,142	1,948	30/06/2022
5	EE	Federal	HEAT	100	4,265	1,405	5,670	31/12/2021
6	DKV	Federal	aVME1	50	4,495	4,675	9,170	30/11/2020
7	DKV	Federal	aVME2	50	5,680	5,680	11,360	30/06/2022
8	DKV	Federal	HaRaZäN	50	690	709	1,399	30/11/2020
9	DKV	Federal	ROKS-HH	50	15,700	16,319	32,019	31/12/2024
10	DKV	Federal	TLF3.0	50	601	1,126	1,727	31/12/2024
11	CEF	EU	CROADS UN		8,200		8,200	31.12.2023
12	DKV	Federal	GNB+	50	553	750	1,303	30/04/2021
13	DKV	Federal	Congestion forecast	50	1,266	1,535	2,800	31/03/2020
14	DKV	Federal	LSA plus	50	484	616	1,100	31/03/2020
15	DKV	Federal	SmaLa	50	1,060	1,060	2,120	31/03/2024
16	DKV	Federal	#transmove	50	2,605	2,905	5,510	31/12/2024
17	DKV	Federal	QM-IV	50	227	227	455	30/06/2022
18	DKV	Federal	PrioBike-HH	60	3,650	3,650	7,300	31/12/2024
19	mFund	Federal	EDDY	70	562	241	803	31/10/2024
20	EIT UM	EU	CELESTE	70	30	45	75	31/12/2022
21	Horizon Europe	EU	SINFONICA	100	145	47	192	30/08/2025
22	Horizon Europe	EU	MODI	100	1,070	135	1,205	31/03/2026
23	Cyber security for 5G/6G KT	Federal	SILKOSTU	100	149	44	193	31/12/2024
24	DKV	Federal	CARPE DIEM	65	307	483	790	31/12/2024
25	INTERREG BSR	EU	BATS	57	64	50	114	31/05/2026
26	EIB	EU	ITS cube	90	1,945	541	2,486	31/05/2027
27	INTERREG NSR	EU	MegaBITS	60	343	320	663	31/03/2026
28	-		Digital S-Bahn Hamburg 1.0	-	-	63,000	63,000	31/12/2021
29	ACD	Federal	Ahoi	48	18,000	19,000	37,000	31/12/2025
30	ACD	Federal	ALIKE	50	26,000	26,000	52,000	30/06/2026
31	-		Digital S-Bahn Hamburg 2.0	-	-	67,000	67,000	
32	-	Federal	ITS World Congress 2021	26	3,500	10,000	13,500	31/12/2021
33	-	Federal	UITP Summit 2025/2027	72	8,000	3,000	11,000	31/12/2027
34	mFund	Federal	BLU-Space	70	2,700	1,200	3,900	31/05/2026
			Total		**131,787**	**242,412**		

Figure 24: ITS projects (MInistry for Transport and Mobility Transition, Department of Economics and Innovation, State Office for Roads, Bridges and Waterways) with funding shares – as of: December 2023

The funding projects presented are important research and development projects to further advance the digitalisation of mobility in Hamburg. In addition to the desired funding for digital mobility innovations, some projects such as Test Track for Automated and Connected Driving, V2X and ROKS-HH have further benefits for the Free and Hanseatic City of Hamburg. Since these funded projects for infrastructure-to-vehicle communication (I2V) typically involve the complete renewal of traffic light system technology during construction, they also reduce maintenance costs for the Hamburg budget and support the goals of renewing the infrastructure.

Outlook

Following the important milestone of the ITS World Congress 2021, Hamburg continues to lead in Germany as the ‘Metropolitan Model Region for Mobility’. Hosting the UITP World Public Transport Summit in 2025 and 2027 provides Hamburg with an excellent platform to present the goals and projects of the Digital Mobility Strategy to an international professional audience. The international conferences also serve as a lever to provide a platform for industry, science, and the city, and to position project content. Until 2030, visionary and consistent action will be required to implement the strategic goals and further develop Hamburg’s modern, future-proof, and sustainable mobility system through digitalisation measures. This will make it possible to achieve a significant change in the modal split in favour of eco-mobility. The Digital Mobility Strategy makes an important contribution to this with the development paths and measures outlined.

5 Appendix

5.1 Sources and reference documents

Authority for the Environment, Climate, Energy and Agriculture (2022): Key Points Paper for the Second Update of the Hamburg Climate Plan. Available at https://www.hamburg.de/contentblob/16763680/bdac8f8d932cbd784b9256426fc5b11b/data/d-eckpunktepapier2022.pdf

Department of Economics and Innovation (2023): Digital strategy #2 of the Department of Economics and Innovation. Available at https://digital.hamburg.de/resource/blob/676174/3ad4858903b5f6ee4e182662cc14a80b/pdf-bwi-digitalstrategie-2-0-data.pdf

Department of Economics and Innovation (2020): Digital Strategy for Hamburg. Available at https://www.hamburg.de/contentblob/13508768/703cff94b7cc86a2a12815e52835accf/data/download-digitalstrategie-2020.pdf

Department of Economics, Transport and Innovation (2018): Hamburg Green City Plan. Master plan for the design of sustainable and emission-free mobility in Hamburg as part of the Clean Air Immediate Action Programme 2017–2020. Available at https://www.hamburg.de/contentblob/11221954/582ba457616514510af6efd761b8d5f3/data/masterplan-greencityplan-hamburg.pdf

City Council of the Free and Hanseatic City of Hamburg (2021): Urban Logistics Hamburg - Last Mile Strategy. Document: 22/5939. Available at https://www.buergerschaft-hh.de/parldok/dokument/77388/urbane_logistik_hamburg_strategie_fuer_die_letzte_meile.pdf

City Council of the Free and Hanseatic City of Hamburg (2018): Progress Report on the ITS Strategy. Document: 21/13503. Available at https://www.hamburg.de/contentblob/11233022/118138471ce86af50368f0231911e1c8/data/fortschrittsbericht-der-its-strategie.pdf

City Council of the Free and Hanseatic City of Hamburg (2015): Hamburg Climate Plan. Document: 21/2521. Available at https://www.hamburg.de/contentblob/4658414/b246fbfbbf114918443170697270950 8/data/d-21-2521-hamburger-klimaplan.pdf

Free and Hanseatic City of Hamburg (2016): Transport 4.0. ITS Strategy for Hamburg. Strategy for the Development and Implementation of Intelligent Transport Systems (ITS) in Hamburg. Available at https://www.hamburg.de/contentblob/5934418/2afc89cd64f950803e25689ad3e5db87/data/its-strategie-fuer-hamburg.pdf

Free and Hanseatic City of Hamburg (2014): Master Plan for the Further Development of Publicly Accessible Charging Infrastructure for Electric Vehicles in Hamburg. Available at https://www.hamburg.de/contentblob/4362700/58e4d12870ea16696073d63eb664dfff/data/pm-26-08-2014-masterplan.pdf

Free and Hanseatic City of Hamburg (2019): Comprehensive Expansion of Public Transport in Hamburg. Available at https://www.hamburg.de/pressearchiv-fhh/13330322/2019-12-11-pr-bwvi-hamburg-takt/

MOIA (2021): Ride pooling in Hamburg on the Path to the Future, Berlin. Available at: https://www.moia.io/news-center/downloads/211207_MOIA_Ergebnisbericht_Begleitforschung.pdf

MOIA Mobility Consulting (2024): MIA Visualisation for a Fleet of 2,500 and 10,000 Autonomous On-Demand Shuttles in Hamburg. Available at https://solutions.moia.io/de-DE/mobility-consulting

5.2 Selected measures proposed by participants from strategy development workshops

Proposed measures	***Reason***
Provision of high-resolution maps (HD maps) for autonomous driving	• Accurate mapping of the road conditions and environment • Precise information for safe and efficient navigation • Continuous monitoring and updating for timeliness and accuracy
Utilisation and integration of EO data (earth observation/ satellites) for the operation of drones	• EO data for precise navigation and monitoring of drones • Increasing safety in air traffic • Identification and avoidance of obstacles (buildings, power lines, construction cranes, etc.) • Control and optimisation of traffic by monitoring airspace and capacity
Align service catalogue for the development of digital twins with specialist requirements	• Service catalogue provides an overview of available data and services and ensures that data can be used correctly and efficiently • Adaptation to technical requirements necessary • Insufficient or inconsistent data can impair the development of digital twins
Autonomous fleets in public transport are to be integrated into the hvv switch app and can be booked via the mobility platform	• Better availability and accessibility for users • Integration in hvv switch app and bookable via mobility platform • Facilitated use and improved mobility • Possibility of combining different modes of transport • Better networking of public transport.
Digital curbside management	• Improved efficiency and safety at the roadside • Automated monitoring and control of activities • Better coordination, reduced conflicts, and delays • Optimisation of road space utilisation and traffic relief • Reduction of parking pressure
A comprehensive, multimodal, and digital mobility platform that provides information on intermodal and multimodal mobility services across different providers and enables planning, booking, and payment across these providers	• Standardised source of information for intermodal and multimodal mobility services • Easy accessibility for users • Improved planning and organisation of daily mobility needs • Simplified booking and payment for mobility services • Cross-provider solution • Improved user experience and increased customer loyalty • Optimisation of transport in Hamburg • Promotion of sustainable mobility

Use digital traffic signs and charging points for commercial transport	• Transmission of real-time information on traffic conditions and restrictions to commercial transport services • Digital traffic signs allow the authorities to adapt traffic regulations more quickly • By strategically placing and utilising charging points, commercial transport can facilitate the transition to more environmentally friendly drives and reduce emissions
Asset sharing, such as through a car parking space exchange	• Objective: Reduction of the car parking space shortage through asset sharing • Private parking spaces that are unused during the day are made accessible to other users through a platform • A parking space exchange enables residents and businesses to offer their unused parking spaces • Reduction of road congestion through more effective use of existing car parks • Potential additional income for landlords by renting out unused car parks
Harnessing Hamburg's potential in the field of brownfield digitalisation	• The existing infrastructure, technological expertise, collaboration and networking, promotion of innovation, and commitment to sustainability and environmental awareness provide a solid basis for the integration of digital technologies and solutions

Figure 25: Selected proposed measures from the seven ITS workshops in the period (Q2 2022–Q1 2023) for the strategy update

5.3 Target achievement for the ITS strategy action areas by 2021

Six action areas were defined in the progress report on the ITS strategy (see document: 21/13503): 'Data and Information', 'Intelligent Traffic Control and Management', 'Intelligent Infrastructure', 'Intelligent Parking', 'Mobility as a Service' and 'Automated and Connected Mobility'. During the preparatory work for the Digital Mobility Strategy, the milestones of the ITS strategy planned in 2018 were analysed to determine the status of target achievement. It should be noted that the number of projects at the time of the update was significantly lower than it was at the end of 2021. The objectives formulated in 2018 therefore do not fully cover the current Digital Mobility Strategy project portfolio, which is why they are being further developed and updated in this strategy.

Comparison of the goals of the 2018 progress report and the status (2021), ITS action area of **data and information**:

Target by 2021	***Relevant projects***	***Status***	
Development of the ITS framework architecture as part of the Urban Data Platform for Hamburg	ITS framework architecture	The structure of the ITS framework architecture has been finalised. The framework architecture is constantly being further developed in line with requirements.	
The data and information collected, recorded and generated as part of the ITS strategy will be made available to stakeholders within the Free and Hanseatic City of Hamburg and also to (private) third parties via UDP_HH, provided there are no data protection or security aspects to the contrary.	ITS framework architecture, all projects that generate corresponding data	The data and information collected, recorded, and generated as part of the ITS strategy will be made available to stakeholders within the Free and Hanseatic City of Hamburg and also to (private) third parties via UDP_HH, provided there are no data protection or security aspects to the contrary.	
An overview of the data and information used, generated and, where applicable, further data and information required in the ITS projects is available.	ITS framework architecture, ITS dashboard	An option has been created in the ITS dashboard to provide information on utilised and generated data. All project managers were instructed to complete the dashboard accordingly. This has been accomplished for the most part. This provides a comprehensive overview of the data used, generated, and required.	
Approximately 420 traffic signal systems are equipped with thermal imaging cameras for lane-specific, classified traffic counting for both cars and lorries.	Automated traffic volume recording	The thermal imaging cameras provide reliable data for traffic counting. The classification and travel times of the vehicles have not yet been fully enabled. (Follow-up measure planned).	

The milestones of the ITS strategy in the ‘Data and Information’ action area have been achieved, since the ITS framework architecture has been established as part of the Urban Data Platform for Hamburg, making traffic-related data and information accessible. There is also an overview of the data and information used, generated, and required in ITS projects. At least 420 traffic lights have been equipped with thermal imaging cameras for traffic counting. A count of vehicles categorised by classes (cars, lorries, etc.) and the measurement of travel times using the cameras have not yet been achieved.

The following milestones in the action area of **smart traffic control** and management were achieved by 2021:

Target by 2021	***Relevant projects***	***Status***	
The technical foundations for cross-modal control and management of traffic participants have been implemented. Experience is being gathered for partially and fully automated traffic management.	#transmove, TIMS Traffic Information Management System (demonstrator)	Establishment of the 'data lake' for traffic and mobility forecasts. Test version established within #transmove including chat function between participating operations centres and control centres.	
Initial test areas of the infrastructure are capable of direct communication with traffic participants and interact with those equipped accordingly (both motorised and non-motorised). This includes, among other things, at least 70 traffic signal systems, a drawbridge, and traffic and strategy computers. *Approximately 420 traffic lights are equipped with detectors for lane-specific, classified traffic counting.*	ROKS-HH, TAVF, G4Tc, ITS-Cube	The objective was achieved. The test track has been set up and will be expanded further. Thermal imaging cameras were rolled out.	
Access to 70% of all traffic-related data, with 20% of this data being used (for network control, demand-driven public transport optimisation, and quality analysis of the traffic network)	ITS framework architecture, UDP-HH, ANC (Adaptive Network Control) – Eidelstedter Platz, QUASIBUS, BiDiMoVe	Percentages not measurable. ANC was successfully piloted, which resulted in an optimisation of the traffic flow. In bidirectional, multimodal, networked systems, bus prioritisation has been successfully implemented and will be rolled out in subsequent projects. With QUASIBUS, a tool for the quality assurance of bus priority systems has been developed.	
Initial significant projects for V2X communication, including BiDiMoVe and Green4Transport, as well as the Automated Driving Test Field (see action area 'Automated and Connected Mobility'), have been implemented.	DigiPark, #transmove (including TIMS), PrioBike-HH, ROKS-HH/ Test Track for Automated and Connected Driving, BOS-Realtime Navigation. Additional projects in preparation: ITS-Cube, Mobility Operating System (MOS)	BiDiMoVe and Green4Transport were successfully completed. Additional V2X projects are in progress (see status).	

Technical foundations for cross-traffic control and management of road users have been implemented and experience is being gathered for semi- and fully-automated traffic management.	#transmove, tests on the test track	A comment/chat function was set up for the control centres. A wide variety of innovative mobility applications were tested and analysed on the test track, which is open to all users and manufacturers.	

The milestones of the ITS strategy in the action area 'Intelligent Traffic Control and Management' have been achieved thanks to a comprehensive technical infrastructure that enabled cross-modal traffic control and management. Experience in the field of semi- and fully-automated traffic management was gathered by establishing test areas that could directly communicate with road users. The Urban Data Platform and key databases, such as the 'Data Lake' of the State Office for Roads, Bridges and Waterways, were established for access to traffic-related data. In addition, innovative technologies such as thermal imaging cameras and V2X projects were integrated, which resulted in an optimisation of the traffic flow. Other measures contributed to the successful testing of bus traffic prioritisation. Only the cross-modal control and management of road users was initiated with #transmove, but has not yet been fully realised.

The following milestones from the **smart infrastructure** action area were achieved by 2021:

Target by 2021	***Relevant projects***	***Status***	
Most elements of the technical traffic infrastructure (such as traffic lights, route control systems, permanent counting stations, etc.) are connected to the central system and report their operational status. *Error messages can be analysed manually.*	Connection to roadside units, I2PANEMA, AI inspection drone and I3-LAB VAM	All roadside units installed in the Hamburg metropolitan area are connected to a central monitoring centre at HHVA. In addition, the projects I2PANEMA, AI Inspection Drone, and I3-LAB VAM will provide future data from which information about the condition of the infrastructure can be derived. The same applies to the axle load scale project, which has already been completed.	
The first automated and connected driving test fields are equipped.	Test Track for Automated and Connected Driving, HEAT, BiDiMoVe, dLSA, Green4Transport, ROKS-HH	Over 100 traffic lights in various test areas for automated and connected driving have already been equipped with a roadside unit.	

The process for obtaining permits for oversized and heavy transports has been digitalised, and all permit-relevant infrastructure data are integrated into the process.	iGSM, VEMAGS	The iGSM project was completed in 03/2021. The State Office for Roads, Bridges and Waterways has adopted the NOVALAST system and, to the best of our knowledge, has put it into operation. With the formation of the MInistry for Transport and Mobility Transition, the responsibility for processing oversized and heavy transport applications was transferred from the State Traffic Authority to the Traffic Directorate (VD1) of the BIS. NOVALAST will not be used there.	
Pilot applications not related to the core field have been implemented on existing infrastructure.	Test Track for Automated and Connected Driving, HEAT, BiDiMoVe, Hamburg Box, Box – The Collection Station (DB), mySmartLife, HaRaZäN	More sensors are being installed on existing infrastructure (such as in public lighting) to count bicycles, enhance the safety of vulnerable road users, and offer additional services (for instance, Wi-Fi). The option of taking parcels to railway stations is being further expanded.	

The milestones of the ITS strategy in the 'Intelligent Infrastructure' action are have been achieved, since there is now centralised networking and monitoring of the technical transport infrastructure. Monitoring and error messages make it possible to organise processes more efficiently and evaluate them manually. In addition, the approval process for oversized and heavy transport was digitalised and continued. The implementation of pilot applications on existing infrastructure also contributed to reaching the milestone.

The following milestones in the action area of **smart parking** were achieved by 2021:

Target by 2021	***Relevant projects***	***Status***	
Identification and commissioning of several technical approaches for car park occupancy forecasting and car park utilisation control for a minimum of 8,000 parking spaces, distributed across all extended city centres.	1. Digital parking (cooperation with Telekom) 2. Future parking real-world lab – Car park management	1. Approximately 1,110 ground sensors have been embedded flush with the road surfaces in various districts of the Free and Hanseatic City of Hamburg. These sensors are connected directly to the mobile network via a 'Narrowband Internet of Things' (NB-IoT) interface and transmit their data to the associated backend system; Survey of public parking spaces in all control areas of the State Traffic Authority Car Park Management (approximately 200,000 parking spaces recorded by the end of 2021). 2. Parts of the issue were transferred to the 'Digitalisation management/car park control (DigiParK)' project.	
Simplified, digitalised payment processes.	Digital parking (cooperation with Telekom)	The T-Systems app 'Park and Joy' for mobile parking and navigation to forecasted available parking spaces was available through the Android and iOS App Stores until the end of November 2020, after which the app's operation was discontinued. Several other providers are now active on the market.	

Occupancy information for at least 20,000 car parking spaces based on several data sources; data is available to UDP-HH, for example.	Digital parking (cooperation with Telekom)	Data from the approx. 1,110 sensors was made available to the State Traffic Authority. Tests revealed discrepancies between the occupancy forecast for the monitored parking spaces and the actual situation. Real-time occupancy data from the sensors is relatively accurate but is only available in insufficient numbers and with inadequate area coverage (1,110 sensors compared to several hundred thousand parking spaces). Currently no use case defined for utilising the data.	
Integration in mobility platform (hvv switch) via integrated offers (including P+R car parks).	Digital car park management for hvv switch	The collaboration between the State Traffic Authority and Telekom led to a further partnership between switch and Telekom. In this new collaboration, key insights from the State Traffic Authority's sensor testing were implemented and numerous switch points were equipped with Telekom's sensors.	
Reduction in parking space search traffic	Future Parking real-world lab - car park management, collaborative routing at major events	Mobile recording of the car park, collaborative routing with NUNAV as app-based route guidance within virtual corridors.	

The milestones of the ITS strategy in the 'Smart Parking' action area were partially achieved, such as the identification and implementation of technical approaches for car park occupancy forecasting and the simplification of payment processes. However, other goals, such as obtaining occupancy information for at least 20,000 parking spaces and integrating this into the mobility platform hvv switch through integrated services, were not achieved. The goal of identifying and implementing multiple technical approaches for car park occupancy forecasting and utilisation control for at least 8,000 parking spaces in all extended city centres was more than fulfilled with the digitalisation of over 200,000 parking spaces.

The following milestones from the **Mobility as a Service** action area were achieved by 2021:

Target by 2021	***Relevant projects***	***Status***	
The mobility platform hvv switch has been completed with some functions and put into production. This enables easy access to mobility with the use of mobile devices. The entire range of mobility services becomes more transparent and directly usable by incorporating fares and direct payment options, transfer possibilities, and connection points between different mobility services, as well as real-time information on punctuality and availability with direct booking options.	Mobility platform (hvv switch)	100 hvv switch points at public transport hubs and in residential neighbourhoods. hvv switch app with fully integrated partners since 29 June 2020: • 06/2020: hvv Ticketing + MOIA, PayPal payment method • 05/2021: SIXT share • 10/2021: MILES + TIER • 03/2022: Credit card function • 10/2022: Voi • 2023: ShareNow, StadtRAD, cambio (planning), hvv Any, mobility budget	

Realisation of convenient multimodal mobility chains via integrated services.	Mobility platform (hvv switch)	Google Maps integration with the option to jump to the hvv switch app for public transport searches.	
Use of the public transport network using digital payment systems.	Self service terminals, hvv Card, ANDI – hvv Prepaid Card	• The integration of mobile and in-store sales is intended to be simplified for customers through a user-friendly interface design. • Introduction of a customer card and complete networking of all sales, control, and background systems based on a unified standard. • Rechargeable payment card in the hvv (not yet established).	

The milestones of the ITS strategy in the 'Mobility as a Service' action area have been achieved. By integrating different mobility services and enabling direct booking, the entire range of mobility options has become more transparent and directly usable. The mobility platform hvv switch has been established and provides easy access to mobility through the use of mobile devices, including fares and direct payment options. The use of the public transport network by means of digital payment systems contributes to the achievement of these milestones. The display of real-time information and the implementation of convenient intermodal mobility chains within the mobility platform through integrated services will be implemented in the future. If users are looking for a route using public transport, they have been able to switch directly to the hvv switch app since 2021 to obtain further information and options, such as booking and payment. This allows users to get a complete overview of all available mobility options and choose the best route without having to switch back and forth between different applications.

The following milestones from the **automated and connected mobility** action area were achieved by 2021:

Target by 2021	***Relevant projects and assessment***	***Status***	
Test routes in public areas have been established and are being used by highly and fully automated vehicles, independent of the manufacturer, as part of testing projects.	Test Track for Automated and Connected Driving Hamburg (TAVF), ROKS, HEAT, BiDiMoVe, dLSA, Green4Transport	• More than 70 traffic signals and a drawbridge equipped with roadside ITS stations (R-ITS-S) • (Thermal imaging) camera systems • Networked construction site barriers • Cooperative environmental sensor technology	

The milestones of the ITS strategy in the 'Automated and Connected Mobility' action area were achieved by 2021, as test routes in public areas were established and used by highly and fully automated vehicles. Manufacturer independence plays an important role in making the technology accessible to all market participants and creating a fair competitive environment. By using test routes in public areas, the technology can be evaluated for its practicality and safety. Additionally, as part of testing projects, partnerships were established between automotive manufacturers, research institutions, and public authorities to collaboratively work on the development and implementation of automated mobility solutions.